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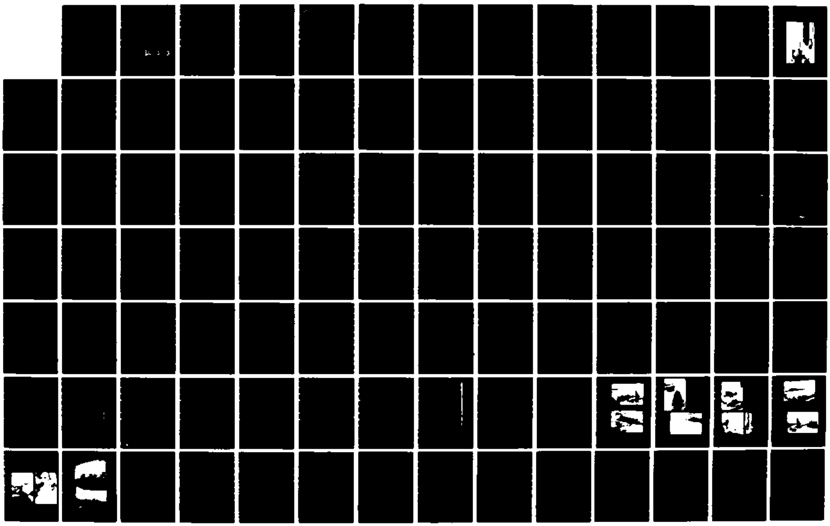

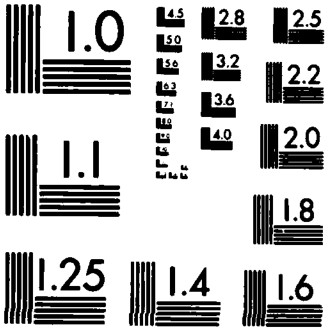
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AD-A157 274

RICHELIEU RIVER BASIN
HARDWICK, VERMONT

HARDWICK LAKE DAM
VT 00186

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

OCT., 1980

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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11. CONTROLLING OFFICE NAME AND ADDRESS DEPT. OF THE ARMY, CORPS OF ENGINEERS NEW ENGLAND DIVISION, NEDED 424 TRAPELO ROAD, WALTHAM, MA. 02254		12. REPORT DATE October 1980
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18. SUPPLEMENTARY NOTES

Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DAMS, INSPECTION, DAM SAFETY,

Richelieu River Basin
Hardwick VT.
Lamoille River

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The dam is a reinforced concrete gravity structure about 523 ft. long and 22.4 fr high. The dam is in fair condition. Conditions which could affect dam stability were noted. It is intermediate in size with a significant hazard potential. There are various remedial measure and recommendations which must be undertaken by the owner.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254

REPLY TO
ATTENTION OF:
NEDED

MAR 06 1981

Honorable Richard A. Snelling
Governor of the State of Vermont
State Capitol
Montpelier, Vermont 05602

Dear Governor Snelling:

Inclosed is a copy of the Hardwick Lake Dam (VT-00186) Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. This report is presented for your use and is based upon a visual inspection, a review of the past performance and a brief hydrological study of the dam. A brief assessment is included at the beginning of the report. I have approved the report and support the findings and recommendations described in Section 7 and ask that you keep me informed of the actions taken to implement them. This follow-up action is a vitally important part of this program.

A copy of this report has been forwarded to the Department of Water Resources, the cooperating agency for the State of Vermont. In addition, a copy of the report has also been furnished the owner, Village of Hardwick, Hardwick, Vermont 05843.

Copies of this report will be made available to the public, upon request, by this office under the Freedom of Information Act. In the case of this report the release date will be thirty days from the date of this letter.

I wish to take this opportunity to thank you and the Department of Water Resources for your cooperation in carrying out this program.

Sincerely,

C. E. EDGAR, III
Colonel, Corps of Engineers
Division Engineer

Incl
As stated

HARDWICK LAKE DAM

VT 00186

RICHELIEU RIVER BASIN

HARDWICK, VERMONT

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

BRIEF ASSESSMENT

PHASE I INSPECTION REPORT

NATIONAL PROGRAM OF INSPECTION OF DAMS

Identification Number:	VT 00186
Name of Dam:	HARDWICK LAKE DAM
Town:	HARDWICK
County and State:	CALEDONIA COUNTY, VERMONT
Stream:	LAMOILLE RIVER
Date of Inspection:	MAY 6, 1980

The dam, constructed about 1920, is a reinforced concrete gravity structure approximately 523 feet long and 22.4 feet in height. The main dam consists of a divided primary ogee crested spillway with a total length of 144 feet, a 38.7 foot long broad crested secondary spillway at the right side, a central structure containing a low level outlet, and a structure at the left abutment containing two additional outlets, one of which is permanently blocked. To the left of the main dam is a non-overflow wing wall about 300 feet long. The upstream face of the dam and the downstream face of the left abutment structure are vertical; the downstream spillway faces are typically sloped at 8-1/4 horizontal to 12 vertical; the downstream face of the central structure is 4-3/4 horizontal to 12 vertical; and the wing wall is battered at about 1 horizontal to 6 vertical. The two outlets are both 6 feet in diameter, the gate for the low level outlet being manually operated, the other electrically operated. Both are reported operable.

The dam impounds Hardwick Lake and is on the Lamoille River approximately 43 miles upstream from Lake Champlain. It is used seasonally to maintain the water level of Hardwick Lake and to a minor extent for stream flow regulation in conjunction with a hydro-electric dam about 3 miles downstream. The lake is 10,000 feet long with a surface area of about 180 acres. Normal storage capacity is estimated at 900 acre-feet.

Based upon the visual inspection and the review of available data regarding this facility, the dam is considered to be in FAIR condition. Conditions which could affect dam stability were noted as follow: continued spalling of the downstream face of the wing wall could eventually compromise the stability of the wall, and continued erosion of the training wall concrete could eventually lead to its collapse amd subsequent weakening of the bridge abutment.

In accordance with the Corps of Engineers Guidelines and the size (INTERMEDIATE) and hazard (SIGNIFICANT) classification of the dam, the Test Flood selected was equivalent to one-half the Probable Maximum Flood (PMF). Peak inflow to the reservoir is 55,500 cfs; routed peak outflow from the dam is 53,300 cfs with the water elevation 6.5 feet above the dam crest. The spillway capacity is 8,400 cfs, which is equivalent to 16% of the routed Test Flood outflow from the dam.

It is recommended that the owner engage a qualified, registered engineer to make recommendations as to applicable materials and techniques to repair the spalled downstream wing wall face, to investigate the training wall in detail and make recommendations for the correction of structural deficiencies, and to perform a detailed hydrologic and hyraulic investigation to further assess the need for and means to increase the project discharge capacity. These and remedial measures which are discussed in Section 7 should be instituted within one year of the owner's receipt of this report.

Stephen D. Murray, P.E.
Project Manager
James W. Sewall Company

STATE OF MAINE
STEPHEN
D.
MURRAY
2736
REGISTERED
PROFESSIONAL ENGINEER

This Phase I Inspection Report on Hardwick Lake Dam (VT-00186) has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgement and practice, and is hereby submitted for approval.

ARAMAST MAHTESIAN, MEMBER
Geotechnical Engineering Branch
Engineering Division

CARNEY M. TERZIAN, MEMBER
Design Branch
Engineering Division

JOSEPH W. FINEGAN, JR., CHAIRMAN
Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

JOE B. FRYAR
Chief, Engineering Division

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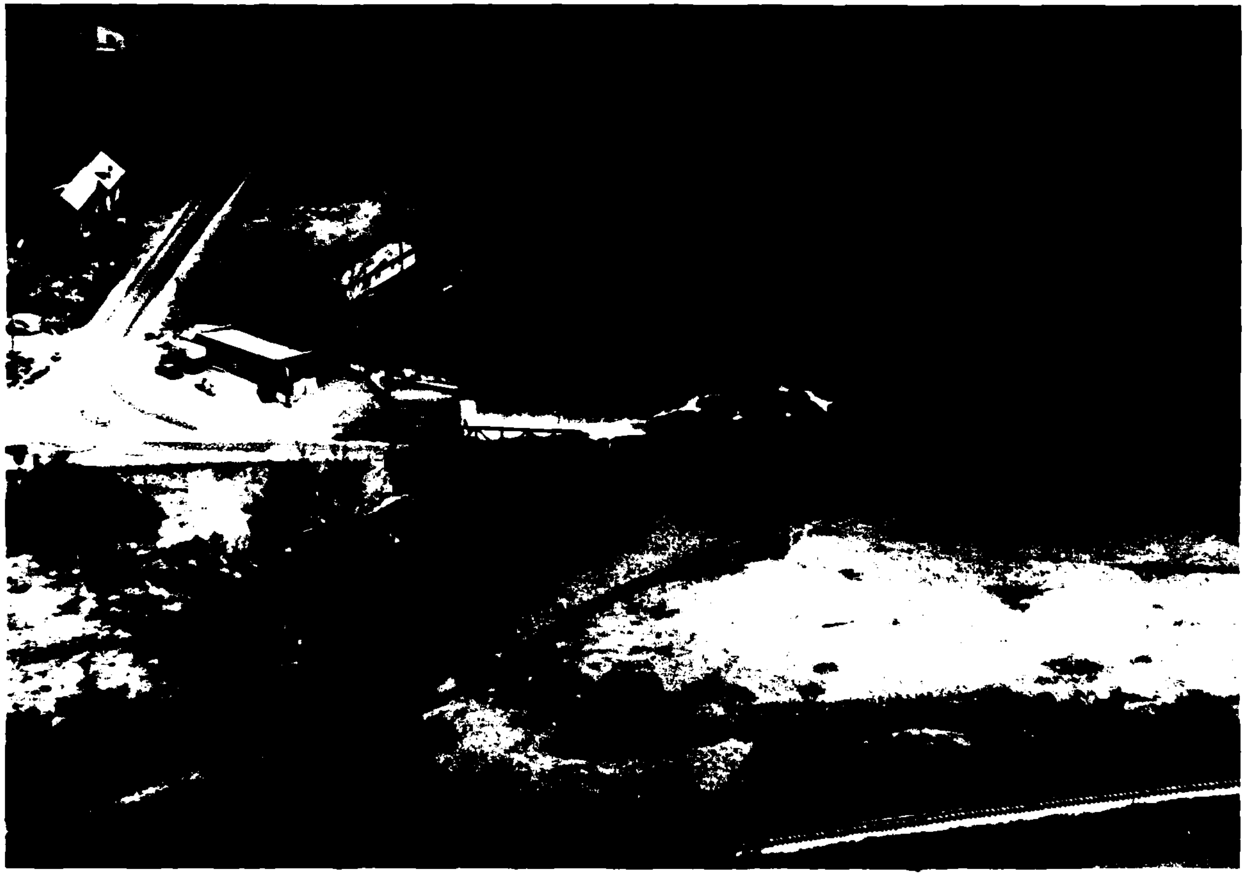
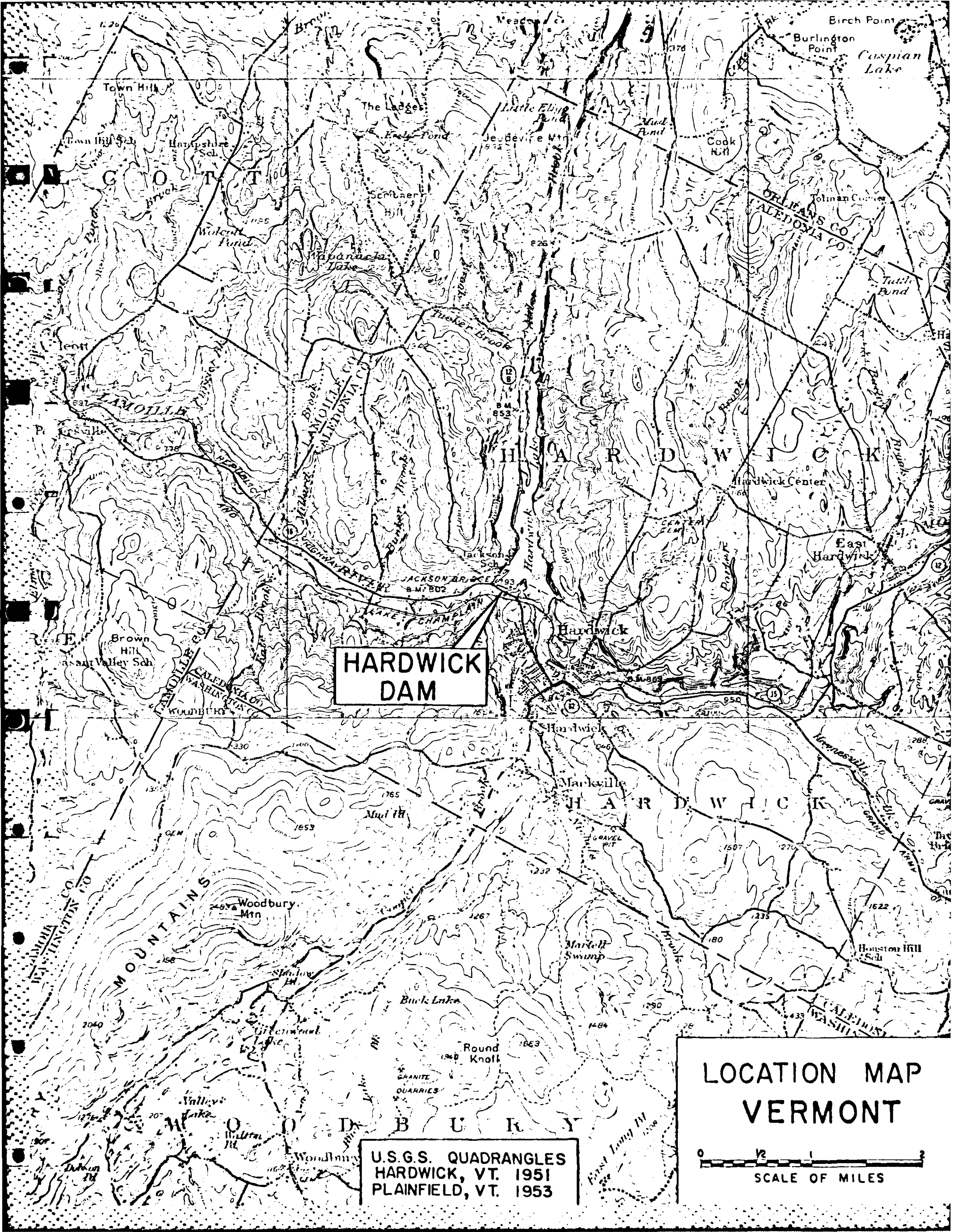
APPENDIX



OVERVIEW PHOTO

U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS	NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS	Hardwick Lake Dam - VT 00186
JAMES W. SEWALL COMPANY CONSULTANTS OLD TOWN, MAINE		Hardwick, Vermont April 22, 1980



HARDWICK DAM
LOCATION MAP
VERMONT
0 1/2 1 2
SCALE OF MILES
U.S.G.S. QUADRANGLES
HARDWICK, VT. 1951
PLAINFIELD, VT. 1953
Town Hill
The Ledges
Jeudevine Mtn
Cook Hill
Caspian Lake
Burlington Point
Birch Point
Scribner Hill
ORLEANS CO
CALEDONIA CO
LAMOILLE CO
Tucker Brook
H A R D W I C K
Hardwick Center
East Hardwick
Jackson Sch
JACKSON BRIDGE
Hardwick
Brown Hill
S Hardwick
Mackville
Mud Pd
Woodbury Mtn
MOUNTAINS
Martell Swamp
Buck Lake
Round Knoll
GRANITE QUARRIES
Houston Hill Sch
W O O D B U R Y

PHASE I INSPECTION REPORT

HARDWICK LAKE DAM

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority - Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. James W. Sewall Company has been retained by the New England Division to inspect and report on selected dams in the State of Vermont. Authorization and notice to proceed were issued to James W. Sewall Company under a letter of April 2, 1980 from William E. Hodgson, Jr. Colonel, Corps of Engineers. Contract No. DACW 33-80-C-0051 has been assigned by the Corps of Engineers for this work.

b. Purpose of Inspection Program - The purposes of the program are to:

1. Perform technical inspection and evaluation of non-federal dams to identify conditions requiring correction in a timely manner by non-federal interests.

2. Encourage and prepare the States to quickly initiate effective dam inspection programs for non-federal dams.

3. To update, verify and complete the National Inventory of Dams.

1.2 DESCRIPTION OF PROJECT

a. Location - The dam is located at the outlet of Hardwick Lake, an impoundment of the Lamoille River, about 7.5 miles upstream from its confluence with Wild Branch and 43 miles upstream from Lake Champlain in the Town of Hardwick, County of Caledonia, State of Vermont. The dam is shown on the Hardwick USGS Quadrangle Map having coordinates latitude N 44° 31.0' and longitude W 72° 22.7'. The dam is popularly called "Jackson Dam".

b. Description of Dam and Appurtenances - The dam, initially constructed about 1920 and reconstructed in 1952, has a total length of approximately 523 feet, including a divided primary spillway with a total length of 144 feet, a 38.7 foot long secondary spillway at the right side of the dam, a central structure containing a low level outlet, a structure at the left abutment of the main dam containing two additional outlets, and a non-overflow wing wall extending about 300 feet to the left of the left abutment of the main dam. Maximum dam height from the bottom of the downstream channel is 22.4 feet. The primary spillway has a crest elevation of 794.8, 13 feet above the downstream channel; the crest of the secondary spillway is 2.5 feet higher. The primary spillway has an ogee crest with a downstream slope of 8-1/4 horizontal

to 12 vertical. The secondary spillway is broad-crested. The upstream face of the dam is vertical.

The central sluiceway pier, with a downstream slope of 4-3/4 horizontal to 12 vertical, has a breadth of about 20 feet and a crest length of 15 feet at elevation 804.8. A 6 foot diameter low level outlet runs through this pier at an invert elevation of about 780. The manually operated gate control mechanism is accessed via a footbridge from the left abutment of the main dam.

The left abutment section, with a width of 13.75 feet and length along the dam axis of 25 feet has a crest elevation of 801.0, a vertical downstream face, and houses two 6 foot diameter sluiceways at an invert elevation of 786. A wood frame gatehouse exists at this location, housing the electrically powered operator for one gate, the other gate being permanently shut. A downstream training wall extends from this abutment.

To the left of the main dam is a non-overflow concrete wing wall with the 4 foot broad crest at an elevation of 801.0. The upstream face is vertical while the downstream face is battered at about 1 horizontal to 6 vertical.

Elevations are in feet referenced to NGVD datum.

No instrumentation exists at this dam site.

c. Size Classification - INTERMEDIATE - The dam impounds approximately 2100 acre-feet with the water level at the top of the dam, which at elevation 801.0 NGVD is 22.4 feet above the streambed elevation. According to the Recommended Guidelines, the dam is classified as intermediate in size since its impoundment is between 1000 acre-feet and 50,000 acre-feet.

d. Hazard Classification - SIGNIFICANT - If the dam were to be breached, there is potential for considerable downstream damage and loss of no more than a few lives. A bridge, commonly called the "Jackson Bridge", carrying Vermont Route 15 over the Lamoille River about 100 feet downstream of the dam would be destroyed by the sudden 6 foot increase in stage. Further downstream, within 2 miles of the dam, three private or Town roadway bridges would be destroyed by the pre-failure flood. The failure flood wave would cause further damage to these roads, greatly increase the area of agricultural flooding, and increase damage to 4 or 5 commercial buildings situated adjacent to the river, already damaged by the pre-failure flow. The Lamoille Valley Railroad bridge, a unique wooden covered structure 2.8 miles below the dam would suffer increased damage or perhaps be destroyed.

e. Ownership - Village of Hardwick
Hardwick, Vermont 05843
(802) 472-5201

f. Operator - Mr. William Fee, Superintendent
Village of Hardwick Electrical Department
Church Street
Hardwick, Vermont 05843
(802) 472-5201

g. Purpose of Dam - The dam is used to maintain the level of Hardwick Lake during the summer months and to a minor extent for stream flow regulation in conjunction with the Wolcott Dam about 3.8 miles downstream, at which electric power is generated.

h. Design and Construction History - The following information is believed to be accurate based upon plans and correspondence available and from conversations with persons familiar with the history of the dam. Information pertaining to the original construction, believed to have been about 1920, was not available. It is reported that the structure was damaged in the flood of November, 1927 and repairs were attempted in 1930. No further record of repairs to the dam exists until 1952 when the dam was refaced and extensively repaired by O. W. Miller Company of Ludlow, Massachusetts, from plans prepared in 1952 by A. D. Bishop, P.E., of Montpelier.

i. Normal Operational Procedures - The lake is drained each fall and the two operable sluice gates remain open throughout the winter. There are no regular operational procedures other than occasional checking.

1.3 PERTINENT DATA

a. Drainage Area - 122.1 square miles of moderately steep, relatively undeveloped terrain which is approximately 40% open and 60% wooded.

b. Discharge at Dam Site - Discharge is over the spillways, through the 6 foot diameter low level outlet, and through one slightly higher 6 foot diameter outlet, a third 6 foot diameter outlet being plugged and abandoned. Elevations are in feet referenced to NGVD datum.

1.	Outlet Works (conduits) capacity at top of dam el. 801:	
	One 6 foot diameter low level outlet, invert el. 780 :	350± cfs
	One 6 foot diameter sluiceway, invert el. 786 :	350± cfs
2.	Maximum known flood at dam site:	
	November, 1927. Magnitude estimated by Vermont Agency of Environmental Protection:	15,000± cfs
3.	Ungated spillway capacity at top of dam el. 801:	8,400± cfs
4.	Ungated spillway capacity at test flood el. 807.5:	24,600 cfs
5.	Gated spillway capacity at normal pool el. 794.8:	N/A
6.	Gated spillway capacity at test flood el. 807.5:	N/A

7. Total spillway capacity at test flood el. 807.5: 24,600 cfs

8. Total project discharge at top of dam el. 801.0: 8800± cfs

9. Total project discharge at test flood el. 807.5: 53,300± cfs

c. Elevation (Feet, NGVD)

1. Streambed at toe of dam:	778.6
2. Bottom of cutoff:	N/A
3. Maximum tailwater:	789.0
4. Recreation pool:	794.8
5. Full flood control pool:	N/A
6. Spillway crest (Ungated):	794.8 primary 797.3 secondary
7. Design surcharge (original design):	unknown
8. Top of dam:	801.0
9. Test flood surcharge:	807.5

d. Reservoir

1. Length of normal pool:	10,000± ft
2. Length of flood control pool:	N/A
3. Length of spillway crest pool:	10,000± ft
4. Length of pool at top of dam:	11,300± ft
5. Length of test flood pool:	12,500± ft

e. Storage

1. Normal pool:	900 acre-ft
2. Flood control pool:	N/A
3. Spillway crest pool:	900 acre-ft
4. Top of dam:	2100 acre-ft
5. Test flood pool:	3400 acre-ft

f. <u>Reservoir Surface</u>

1.	Normal pool:	180 acres
2.	Flood control pool:	N/A
3.	Spillway crest:	180 acres
4.	Test flood pool:	266 acres
5.	Top of dam:	222 acres

g. <u>Dam</u>

1.	Type:	concrete gravity
2.	Length:	$523^{\pm}$ ft
3.	Height:	22.4 ft
4.	Top Width:	4 ft
5.	Side Slopes:	N/A
6.	Zoning:	N/A
7.	Impervious Core:	N/A
8.	Cutoff:	N/A
9.	Grout Curtain:	N/A
10.	Other:	N/A

h. <u>Diversion and Regulating Tunnel</u> N/A

i. <u>Spillway</u>

1.	Type:	concrete ogee
2.	Length of weir:	182.7 ft
3.	Crest el.	144 ft @ 794.8 38.7 ft @ 797.3
4.	Gates:	N/A
5.	Upstream channel:	N/A

6. Downstream channel: original streambed

7. General: N/A

j. Regulating Outlets

Regulating Outlets	Pond Drain	Sluiceway
1. Invert:	780	786±
2. Size:	6 ft diameter	6 ft diameter
3. Description:	pipe through center pier	pipe through left abutment
4. Control mechanism	manually operated	electrically operated
5. Other:	a third regulating gate same size and elevation as the sluiceway is permanently blocked and abandoned	

SECTION 2: ENGINEERING DATA

2.1 DESIGN

a. Available Data - The available data consists of three sheets of "Details for Repair, Hardwick Village Storage Reservoir" by A. D. Bishop, dated June and August, 1952.

b. Design Features - The drawings, computations and inspection reports indicate the design features stated in Section 1.

c. Design Data - Design data consists of information on the three drawings by A. D. Bishop as listed in "Available Data".

2.2 CONSTRUCTION

a. Available Data - Information as contained in any plans, drawings, or specifications previously listed in "Design Data" or Appendix B.

b. Construction Considerations - A minor variation was noted in the existing dam compared to the repair drawings of 1952. The plans show a secondary spillway at the right end of the dam. This was 39 feet long, one foot above the main spillway, and the downstream face was formed by a granite block wall. This secondary spillway is now 30 inches above the primary spillway, and the granite blocks have either been replaced by or capped with concrete as seen in the left background of Photo 2.

2.3 OPERATION

Pond level readings are not taken on any regular schedule. No formal operation procedures are known to exist.

2.4 EVALUATION

a. Availability - Existing data was provided by the owner.

b. Adequacy - Detailed hydrologic/hydraulic data were not available. Design data and field measurements were utilized in conjunction with New England Division - Army Corps of Engineers "Preliminary Guidance for Estimating Maximum Probable Discharges" to perform the computations of outflow capacity.

The detailed engineering data required to perform an in-depth stability analysis of the dam was not available. The final assessment of the dam, therefore, must be based primarily on visual inspection, performance history, and spillway capacity computations.

c. Validity - A comparison of records, data, and visual observations reveals no significant discrepancies, other than those noted above, between design and as-built dimensions.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General - At the time of inspection on May 6, 1980, the water level in Hardwick Lake, impounded by the dam, was 1 inch over the primary spillway. The weather was sunny and mild. The general condition of this dam is fair.

b. Dam - The main dam is a reinforced concrete gravity structure consisting primarily of an ogee shaped spillway divided by a central pier containing the low-level pond drain, as shown in Photo 1. The concrete of the main dam appears in good condition with only minor cracks and efflorescence.

The main dam is founded on bedrock which is exposed at both abutments and in the channel immediately downstream as shown in Photos 1 and 2.

A reinforced concrete non-overflow wing wall, shown in Photo 3, extends about 300 feet left from the left abutment of the main dam. The 4 foot wide top is 6 feet above the spillway crest; the upstream face is vertical while the downstream face is battered at about 1 horizontal to 6 vertical. The wing wall concrete is in fair condition. As shown in Photo 4, the downstream face is extensively spalled with practically no original surface remaining.

c. Appurtenant Structures

Spillway

As shown in Photo 1, the main spillway is an ogee section divided by a central pier. A short secondary spillway integral with the right abutment is shown in Photo 2. As far as could be observed, the spillway concrete is in good condition. Discharge from much of the left side of the main spillway is obstructed by bedrock projections, the top of which are nearly equal to spillway crest elevation as shown in Photo 8. No debris or other obstructions to flow were visible. Provision for flashboard attachment exists, although it is reported that none are used on the dam.

Outlet Structures

A low level outlet is contained within the central pier shown in Photos 1 and 8. The outlet gate mechanism is a manually operated rack and pinion type. The outlet is sufficiently low to relieve hydrostatic pressure from the dam and to facilitate dam repair. The wood deck of the suspended access bridge appeared deteriorated and unsafe. Access was therefore not attempted by the inspection team. As far as could be seen, the mechanism is in good condition and is reported to be operable.

Two additional outlets, at a higher elevation, are located in the left abutment of the main dam as shown in Photo 5. The left outlet gate is operated by an electrically powered rack and pinion mechanism shown in Photo 6 and is reported to be operable although it cannot be closed tightly. The

electrical system is antiquated, shows evidence of arcing and is in fair condition. The other outlet is permanently closed and not operable. The wood frame gate house is in fair condition.

d. Reservoir Area - In the vicinity of the dam, the shores of Hardwick Lake are typically grassy with dispersed deciduous growth. As shown in Photo 7, there are no indications of instability along the banks.

e. Downstream Channel - The channel directly below the dam is exposed bedrock. A reinforced concrete training wall, about 140 feet long, extends along the left side of the discharge channel from the left main dam abutment to the wing wall of the Vermont Route 15 highway bridge as shown in Photo 8. This wall is in generally good condition with minor surface spalling and several horizontal and vertical cracks with no displacement. At the junction with the bridge wing wall, a short section of the training wall is badly eroded as shown in Photos 9 and 10.

The right channel bank between the dam and the bridge consists primarily of dumped rip-rap. Below the Vermont Route 15 highway bridge, known locally as the Jackson Bridge, shown at the top of Photo 9, the Lamoille River meanders through a steep-sided valley about one-half mile wide paralleled by Route 15 and the Lamoille Valley Railroad tracks. The banks are grassy and bordered for the most part by open fields, most residential and commercial structures being considerably distant from and higher than the river, the major exception being a commercial complex about 1.9 miles downstream from the dam and 13 feet above the river channel.

Three light duty bridges, town or privately owned, cross the river between the Route 15 bridge and the covered Lamoille Valley Railroad bridge shown in Photo 11 about 2.8 miles below the dam. Photo 12 shows the second Route 15 crossing about 3.3 miles below the dam. This bridge is the approximate upper limit of the normal impoundment of Wolcott Dam, about 3.8 miles downstream of Hardwick Dam.

3.2 EVALUATION

On the basis of visual examination, the dam is considered to be in fair condition.

Continued spalling of the downstream face of the wing wall could eventually compromise the stability of the wall.

Erosion of the lower end of the training wall, if allowed to continue, could eventually lead to weakening of the highway bridge abutment.

Access to the pier containing the low level outlet is unsafe.

The electrical system for the electrically operated outlet is antiquated and shows evidence of arcing.

SECTION 4: OPERATIONAL AND MAINTENANCE PROCEDURES

4.1 OPERATIONAL PROCEDURES

a. General - The dam is used during the summer to maintain the level of Hardwick Lake and to some extent during periods of low flow to augment flow to the power generating dam about 3.8 miles downstream. The low level outlet is opened in the fall and the lake remains drained until late spring.

b. Warning System - No warning system is known to exist.

4.2 MAINTENANCE PROCEDURES

a. General - The dam receives no regular maintenance.

b. Operating Facilities - No formal plan for the maintenance of operating facilities is know to exist. There are two operable 6 foot diameter outlets with sluice gates. A third outlet is reported to be permanently closed and not operable.

4.3 EVALUATION

The operation and maintenance procedures at this dam are inadequate to insure that all problems encountered can be remedied within a reasonable period of time. The owner should establish a written operation and maintenance procedure as well as a warning system to follow in the event of an emergency at the dam.

SECTION 5: EVALUATION OF HYDRAULIC/HYDROLOGIC FEATURES

5.1 GENERAL

The project is basically a low surcharge storage - high spillage gravity dam constructed for stream flow regulation purposes in concert with a hydro-electric dam further downstream.

The tributary watershed consists of 122.1 square miles of relatively undeveloped terrain which is approximately 40% open and 60% wooded. With NGVD elevations of 800 to over 2,000 feet portions of the watershed are very steep, but average watershed slope is approximately 2%, thus the watershed is considered rolling rather than mountainous in character. Contained within this drainage area are several small lakes other than Hardwick Lake itself, including Caspian Lake, Eligo Pond, Nichols Pond, Long Pond, East Long Pond and Flagg Pond. The aggregate surface area of these lakes comprises less than 2% of the entire watershed area, thus their storage effect on the peak inflow to Hardwick Lake was deemed negligible.

Hardwick Dam is a concrete gravity structure equipped with 182.7 feet of ogee crest spillway. The spillway capacity at the top of the dam is approximately 16% of the routed Test Food outflow with the dam overtopped by 6.5 feet.

5.2 DESIGN DATA

No design data are known to exist for this project.

5.3 EXPERIENCE DATA

The maximum known flood at the dam site occurred in November, 1927, overtopping the dam and reportedly damaging it significantly. No detailed information on this incident was located.

5.4 TEST FLOOD ANALYSIS

The Test Flood for this significant hazard, intermediate size dam, ranges from one-half of the Probable Maximum Flood to the Probable Maximum Flood (PMF). One-half of the PMF was selected as the Test Food since Hardwick Lake Dam is at the lower end of the intermediate size classification and poses a relatively low risk to populated areas.

Peak inflow to Hardwick Lake is 55,600 cfs and was determined using the "Rolling" guide curve of the "Preliminary Guidance for Estimating Maximum Probable Discharge", dated March, 1978. Peak outflow is 53,300 cfs with the water elevation 6.5 feet above the dam crest and the initial reservoir level assumed at the primary spillway crest (el. 794.8 NGVD). Based upon our hydraulics computations, the spillway capacity is 8400 cfs which is approximately 16% of the routed Test Flood outflow from Hardwick Lake Dam.

5.5 DAM FAILURE ANALYSIS

Utilizing the April, 1978, "Rule of Thumb Guidance for Estimating Downstream Dam Failure Hydrographs", the peak failure outflow with the pool initially at the top of the dam (el. 801 NGVD) would be approximately 13,500

cfs. The breach would cause an increase in stage above the pre-failure elevation immediately downstream from the dam of 6.3 feet which would bring the water level approximately equal to the deck of the Vermont Route 15 highway bridge or "Jackson Bridge", and probably destroy it. Three light duty private or Town owned bridges span the river within 2.5 miles of the dam. These bridges would be destroyed by the pre-failure flood, but the sudden increase in stage of 1 to 2 feet would cause additional damage to these roads, greatly increase the area of agricultural flooding, and increase damage to 4 or 5 commercial buildings along the river which would have been flooded about 1 foot above the sills by the pre-failure flow. Further downstream, about 2.8 miles from the dam, a unique wooden covered bridge carrying the Lamoille Valley Railroad over the river would suffer increased damage and perhaps destruction from the sudden 1 foot increase in stage which would bring the water level well up into the lower structural members. Wolcott Dam, about 3.8 miles downstream, has spillway capacity to the top of dam equal to about 138% of the peak failure flow from Hardwick Dam. There is potential for loss of no more than a few lives and considerable property damage, thus Hardwick Lake Dam has been classified as a "Significant Hazard" dam.

SECTION 6: EVALUATION OF STRUCTURAL STABILITY

6.1 VISUAL OBSERVATION

The visual inspection disclosed the following potential structural problems:

1. Continued spalling of the downstream face of the left wing wall shown in Photo 4 could eventually compromise the stability of the wall.

2. Continued erosion of the lower end of the training wall shown in Photo 10 could eventually lead to its collapse and subsequent weakening of the highway bridge abutment.

6.2 DESIGN AND CONSTRUCTION DATA

No original design and construction data are available for the dam.

6.3 POST-CONSTRUCTION CHANGES

Drawings dated 1952 exist which indicate that significant renovations were made to the concrete spillway section of the dam.

A new concrete facing was applied to the overflow sections. Concrete which had deteriorated was removed to a depth of 8 to 12 inches. Reinforcing bars were dowelled into the existing concrete to provide anchorage for the new concrete surface.

The secondary spillway section on the right abutment, which was constructed of granite blocks, is now a concrete section. It is not known if the granite blocks remain in place beneath the concrete surface.

6.4 SEISMIC STABILITY

The dam is located in Seismic Zone 2, and in accordance with the recommended Phase I guidelines does not warrant seismic investigation.

SECTION 7: ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Condition - Based upon the visual inspection, the dam is judged to be in fair condition.

b. Adequacy of Information - Due to the lack of design and construction data for this dam, the assessment of safety is based solely on the visual inspection.

c. Urgency - The remedial measures and recommendations presented below should be implemented by the owner within 1 year after receipt of this Phase I Inspection Report.

7.2 RECOMMENDATIONS

The owner should engage a qualified registered engineer to undertake further investigations as follow:

a. Make recommendations as to applicable materials and techniques to repair the spalled downstream wing wall face.

b. Investigate the training wall in detail and make recommendations for the correction of structural deficiencies.

c. Perform a detailed hydraulic and hydrologic study to further assess the need for and the means to increase the project discharge capacity.

The owner should implement all recommendations by the engineer.

7.3 REMEDIAL MEASURES

a. A program of annual technical inspection, with repairs as necessary, should be instituted by the owner.

b. A formal downstream warning system to be implemented in the event of an emergency at the dam should be developed by the owner.

c. A formal program of operation and maintenance procedures should be instituted and fully documented to provide accurate records for future reference.

d. The owner should arrange for repairs to the wood deck of the foot bridge to the low level outlet structure.

e. The owner should arrange for replacement of gatehouse wiring and electrical devices with modern equipment and materials.

7.4 ALTERNATIVES

This study has identified no practical alternative to the above recommendations.

APPENDIX A

VISUAL CHECK LIST WITH COMMENTS

1

VISUAL INSPECTION CHECKLIST
PARTY ORGANIZATION

PROJECT Hardwick Lake Dam

DATE May 6, 1980

TIME 4 PM

WEATHER Cloudy, mild

W.S. ELEV. ________ U.S. ______ DN.S.

PARTY:

J.W.S. 1. Stephen D. Murray S.D.M.
J.W.S. 2. Rodney L. Hanscom R.L.H.
J.W.S. 3. Charles A. Heney C.A.H.
G.E.I. 4. Daniel P. La Gatta D.P.L.
5. ____________
6. ____________
7. ____________
8. ____________
9. ____________
10. ____________

PROJECT FEATURE	INSPECTED BY	REMARKS
1. Concrete Dam	SDM, RLH, CAH, DPL	
2. Gate House	SDM, RLH, CAH	
3. Outlet Conduit	SDM, RLH, CAH, DPL	
4. Outlet Channel	SDM, RLH, CAH, DPL	
5. Spillway Weir and Discharge Channel	SDM, RLH, CAH, DPL	
6. Service Bridge	SDM, RLH, CAH	
7.		
8.		
9.		
10.		

PERIODIC INSPECTION CHECKLIST

PROJECT [illegible] Lake Dam — DATE May 6, 19[illegible]

PROJECT FEATURE Concrete Dam — NAME S.D.M. R.L.H.

DISCIPLINE James W. Sewall Co. — NAME C.R.H. D.R.L.

Geotechnical Engineers Inc.

AREA EVALUATED	CONDITION
DAM EMBANKMENT	Dam is a concrete structure founded on bedrock which is exposed at both abutments and in the channel immediately downstream of the dam.
Crest Elevation	
Current Pool Elevation	
Maximum Impoundment to Date	A concrete wing wall extends left from the outlet control structure. This is about 300 feet long. It is 2 feet wide and varies in height from 2 to 5 feet.
Surface Cracks	
Pavement Condition	
Movement or Settlement of Crest	
Lateral Movement	The top and upstream face of the wing wall are in fair condition with some areas of spalling. The downstream face is in poor condition with extensive spalling. The spalling varies in depth from 2 to 5 inches. There is practically no original surface remaining on the downstream face.
Vertical Alignment	
Horizontal Alignment	
Condition at Abutment and at Concrete Structures	
Indications of Movement of Structural Items on Slopes	
Trespassing on Slopes	
Sloughing or Erosion of Slopes or Abutments	
Rock Slope Protection - Riprap Failures	The concrete of the main dam consisting of spillway, secondary spillway, gate pier and gate house is in good condition with only minor cracks and efflorescence.
Unusual Movement or Cracking at or Near Toe	
Unusual Embankment or Downstream Seepage	
Piping or Boils	
Foundation Drainage Features	
Toe Drains	
Instrumentation System	
Vegetation	

PERIODIC INSPECTION CHECKLIST

PROJECT *Hardwick Lake Dam* DATE *May 6, 1980*

PROJECT FEATURE ______ NAME *S.D.M. R.L.H.*

DISCIPLINE *James W. Sewall Co.* NAME *C.A.H. D.P.L.*

Geotechnical Engineers inc.

AREA EVALUATED	CONDITION
DIKE EMBANKMENT	*No dike on this project*
Crest Elevation	
Current Pool Elevation	
Maximum Impoundment to Date	
Surface Cracks	
Pavement Condition	
Movement or Settlement of Crest	
Lateral Movement	
Vertical Alignment	
Horizontal Alignment	
Condition at Abutment and at Concrete Structures	
Indications of Movement of Structural Items on Slopes	
Trespassing on Slopes	
Sloughing or Erosion of Slopes or Abutments	
Rock Slope Protection - Riprap Failures	
Unusual Movement or Cracking at or Near Toes	
Unusual Embankment or Downstream Seepage	
Piping or Boils	
Foundation Drainage Features	
Toe Drains	
Instrumentation System	
Vegetation	

PROJECT Harwick Lake Dam

DATE May 6, 1980

PROJECT FEATURE

NAME S.D.M. B.L.H.

DISCIPLINE James W. Sewall Co.
Geotechnical Engineers Inc.

NAME C.B.A. D.P.L.

AREA EVALUATED	CONDITION
OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE	
a. Approach Channel	No approach channel. Intake is below water surface.
Slope Conditions	
Bottom Conditions	
Rock Slides or Falls	
Log Boom	
Debris	
Condition of Concrete Lining	
Drains or Weep Holes	
b. Intake Structure	
Condition of Concrete	
Stop Logs and Slots	

PERIODIC INSPECTION CHECKLIST

PROJECT Horawick Lake Dam DATE May 6, 1980

PROJECT FEATURE Gate House NAME S.C.M. R.L.H.

DISCIPLINE James W. Sewall Co. NAME C.P.H. D.P.L.
Geotechnical Engineers Inc.

AREA EVALUATED	CONDITION
OUTLET WORKS - CONTROL TOWER	
a. Concrete and Structural	
General Condition	Generally good
Condition of Joints	Good
Spalling	None noted
Visible Reinforcing	None visible
Rusting or Staining of Concrete	Minor rust stains
Any Seepage or Efflorescence	Minor efflorescence
Joint Alignment	N. A.
Unusual Seepage or Leaks in Gate Chamber	None observed
Cracks	Minor cracks
Rusting or Corrosion of Steel	Minor rusting
b. Mechanical and Electrical	
Air Vents	N A.
Float Wells	N. A.
Crane Hoist	N. A.
Elevator	N. A.
Hydraulic System	N. A.
Service Gates	Right sluice gate is jammed shut
Emergency Gates	In operating condition, but will not shut completely
Lightning Protection System	N. A.
Emergency Power System	N. A.
Wiring and Lighting System	Antiquated, with evidence of arcing

PROJECT Hardwick Lake Dam DATE May 6, 1980

PROJECT FEATURE Outlet Conduit NAME S.D.M. R.L.H.

DISCIPLINE James W. Sewall Co. NAME C.A.H. D.P.L.

Geotechnical Engineers Inc.

AREA EVALUATED	CONDITION
OUTLET WORKS - TRANSITION AND CONDUIT	
General Condition of Concrete	Good
Rust or Staining on Concrete	Minor
Spalling	None noted
Erosion or Cavitation	None observed
Cracking	Minor cracks
Alignment of Monoliths	N.A.
Alignment of Joints	N.A.
Numbering of Monoliths	N.A.
	There are two 6' diameter outlet pipes below the gate house near the left end of the dam. The low level outlet is a 6' diameter pipe in the center sluiceway pier.

PROJECT Hardwick Lake Dam DATE May 6, 1980

PROJECT FEATURE Outlet Channel NAME S.D.M. T.L.H.

DISCIPLINE James [illegible] Co. NAME C.A.H. D.P.L.
Geotechnical Engineers Inc.

AREA EVALUATED	CONDITION
OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL	There is a reinforced concrete training wall, about 140' long which runs from below the gate house.
General Condition of Concrete	The concrete is in generally good condition with some surface spalling
Rust or Staining	
Spalling	
Erosion or Cavitation	
Visible Reinforcing	There are several horizontal and vertical cracks, with no movement noted at the cracks.
Any Seepage or Efflorescence	
Condition at Joints	
Drain holes	
Channel	Channel is natural river channel.
Loose Rock or Trees Overhanging Channel	None observed
Condition of Discharge Channel	General condition is good

PERIODIC INSPECTION CHECKLIST

PROJECT Hardwick Lake Dam DATE May 6, 1980

PROJECT FEATURE Spillway Weirs and Discharge Channel NAME S.D.M. R.L.H.

DISCIPLINE James W. Sewall Co. NAME C.R.H. D.P.L.
Geotechnical Engineers Inc.

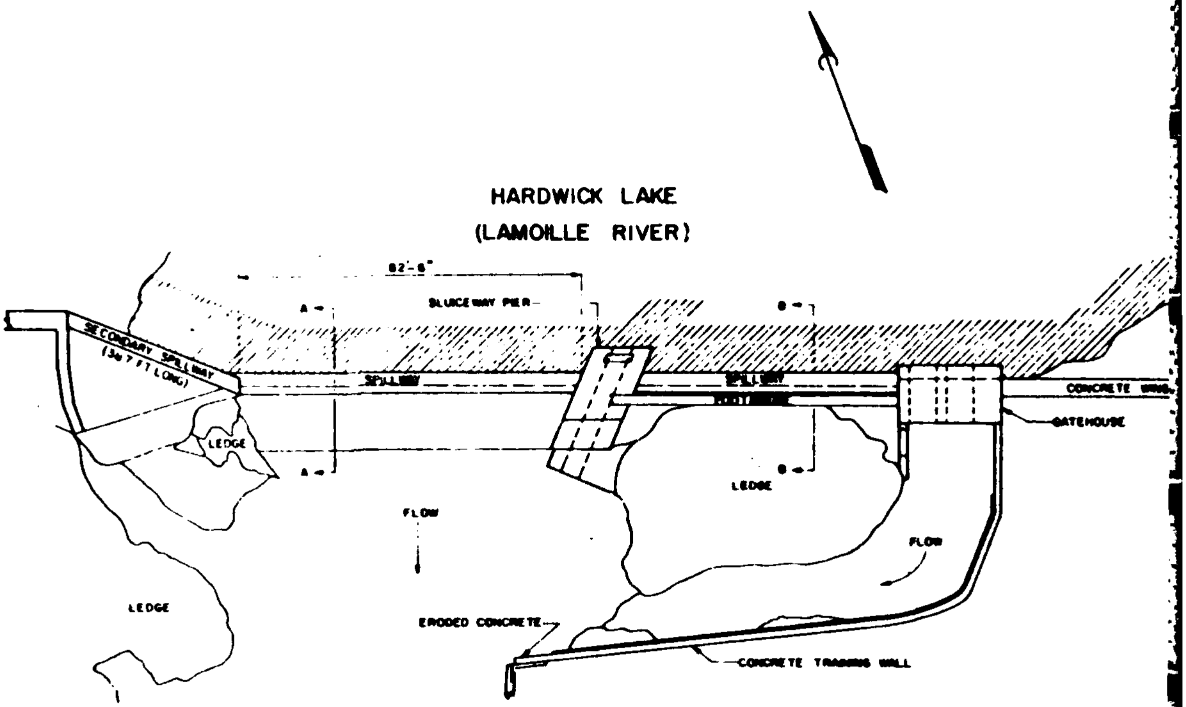
AREA EVALUATED	CONDITION
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS	
a. Approach Channel	Beneath reservoir
General Condition	
Loose Rock Overhanging Channel	
Trees Overhanging Channel	
Floor of Approach Channel	
b. Weir and Training Walls	Training wall on preceding page
General Condition of Concrete	Left spillway - fair condition Right spillway - good condition
Rust or Staining	
Spalling	Spalling on downstream face of left spillway
Any Visible Reinforcing	Wire mesh exposed at top of left spillway in two places
Any Seepage or Efflorescence	
Drain Holes	
c. Discharge Channel	Channel is natural river channel
General Condition	Good
Loose Rock Overhanging Channel	None observed
Trees Overhanging Channel	None
Floor of Channel	Exposed bedrock with uneven surface.
Other Obstructions	None

PROJECT	Horr... Lake Dam	DATE	May 6, 1980
PROJECT FEATURE	Service Bridge	NAME	S.D.M. R.L.H.
DISCIPLINE	James W. Sewall Co. Geotechnical Engineers Inc.	NAME	C.A.H. D.R.L.

AREA EVALUATED	CONDITION
OUTLET WORKS - SERVICE BRIDGE	Suspension bridge using steel rods and turnbuckles from which the wooden deck is hung.
a. Super Structure	
Bearings	N.A.
Anchor Bolts	N.A.
Bridge Seat	N.A.
Longitudinal Members	Wooden stringers are in fair condition
Underside of Deck	Poor condition
Secondary Bracing	N.A.
Deck	Planks of deck are in poor condition.
Drainage System	N. A.
Railings	None
Expansion Joints	N.A.
Paint	None on deck
b. Abutment & Piers	
General Condition of Concrete	Good for Gate House Pier and Center Sluiceway Pier
Alignment of Abutment	Good
Approach to Bridge	Gate House Pier forms the approach
Condition of Seat & Backwall	N.A.

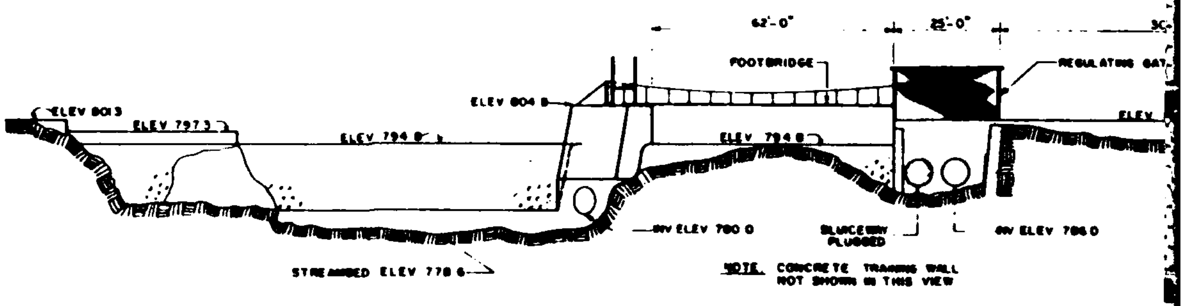
APPENDIX B

ENGINEERING DATA



PLAN

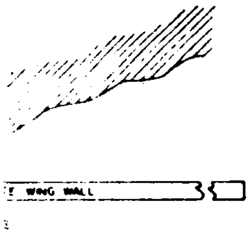
20 10 0 20 40

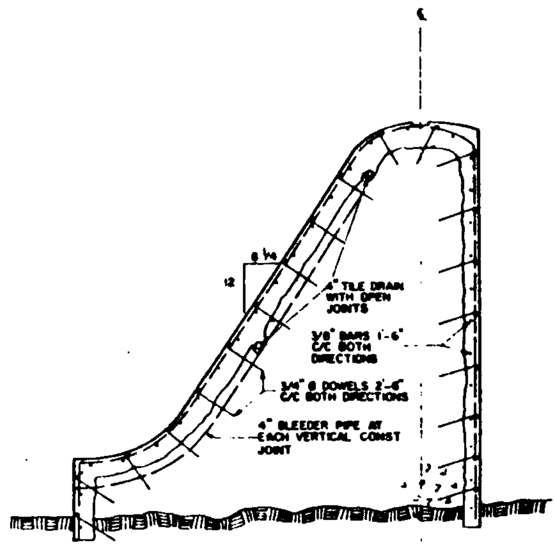


PROFILE

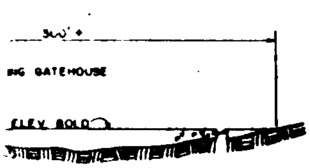
20 10 0 20 40

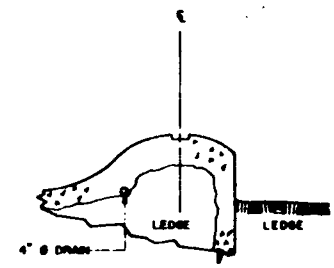
1012





SECTION A-A





NOTE: THIS PLAN COMPILED FROM EXISTING PLANS FOR DAM RECONSTRUCTION IN 1952 BY A.D. BISHOP, ENGINEER, AND MODIFIED AS OBSERVED IN THE FIELD.

SECTION B-B

U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS	JAMES W. SEWALL COMPANY CONSULTING ENGINEERS	NATIONAL PROGRAM OF INSPECTION OF NON-FEDERAL DAMS HARDWICK LAKE DAM HARDWICK, VT.	B-1
NO. REVISION DATE CK	Design / Drawn / Check / Approved	Date	SHEET OF

HARDWICK LAKE DAM

EXISTING PLANS

On file with the Town of Hardwick:

1. Plan of Hardwick Village Storage Reservoir
   Junction Routes 15 and 12B
   Hardwick, Vermont
   A. D. Bishop, June 13, 1952
   Jackson Dam, Sheet 1

2. Details for Repair - Hardwick Village Storage Reservoir
   Junction Routes 15 and 12B
   Hardwick, Vermont
   A. D. Bishop, June 21, 1952
   Jackson Dam, Sheet 2

3. Details at Center Pier - Jackson Dam
   Junction Routes 15 and 12B
   Hardwick Village, Vermont
   A. D. Bishop, August 9, 1952, Sheet 3

SUMMARY OF DATA AND CORRESPONDENCE

DATE	TO	FROM	SUBJECT	PAGE
5-10-73	File	D.H. Spies Dam Engineer	Hydraulic Comps	B-4
1-28-53	Public Service Commission	Stephen Haybrook Hydraulic Engineer	Inspection Report	B-14
10-27-49	Public Service Commission	Stephen Haybrook Hydraulic Engineer	Inspection Report	B-22
1952	-	A.D. Bishop	Plans for repair - Reduced in size	B-29

AJR
DHS [illegible] May 19 [illegible]

File Hardwick Lake Dam

Spillway Capacity $Q = CLH^{1.5}$

① Before overflow Spillway

(a) Primary $L = 80'$ $H = 2.6'$ $C = 4.0$

$$Q_p = 4.0(80)(2.6)^{1.5}$$

$$Q_p = 1340 \text{ cfs}$$

(b) Secondary $L = 60'$ $H = 2.6'$ $C = 3.5$

$$Q_s = (3.5)(60)(2.6)^{1.5}$$

$$Q_s = 872 \text{ cfs}$$

$$Q_{2.6} = Q_p + Q_s = 1340 + 872 = 2212$$

② Before going over End Wing Wall

(a) Primary $L = 80'$ $H = 6.5'$ $C = 4.0$

$$Q_p = (4.0)(80)(6.5)^{1.5}$$

$$Q_p = 5280 \text{ cfs}$$

b) Secondary $H = 6.5$, $L = 60$, $C = 3.5$

$$Q_s = (3.5)(60)(6.5)^{1.5}$$

$$Q_s = 3460$$

c) Overflow Spillway

$L = 40$, $C = 3.0$, $H = 4.0$

$$Q_o = (40)(3.0)(4.0)^{1.5}$$

$$Q_o = 960 \text{ cfs}$$

$$Q_{6.5} = Q_p + Q_s + Q_o$$

$$= 5280 + 3460 + 960$$

$$= 9700 \text{ cfs}$$

(3) (5) Q_8

At 8 feet above spillway Elev.

a) $Q_p = (8)^{1.5}(4.0)(80) = 7250$

b) $Q_s = (8)^{1.5}(3.6)(60) = 4750$

c) $Q_0 = (5.5)^{(1.5)}(3.0)(40) = 1530$

d) Q Abutment

say $L = 300, H = 1, C = 3.0$

$Q_a = (300)(3.0)(1)^{1.5} = 1000$ cfs

$Q_8 = Q_p + Q_s + Q_o + Q_a$

$= 7250 + 4750 + 1530 + 1000$

$= 14,530$ cfs

At Hardwick Dam

1977 flood = 15,000 cfs = Q_{200+}

= ~~Q_{200+}~~

~~Q_{100} = 12,300 cfs~~

at Johnson ~~RTE~~ $Q_{100} = 28,500$

$Q_{200} = 41,300$

H.H. Hardwick Dam

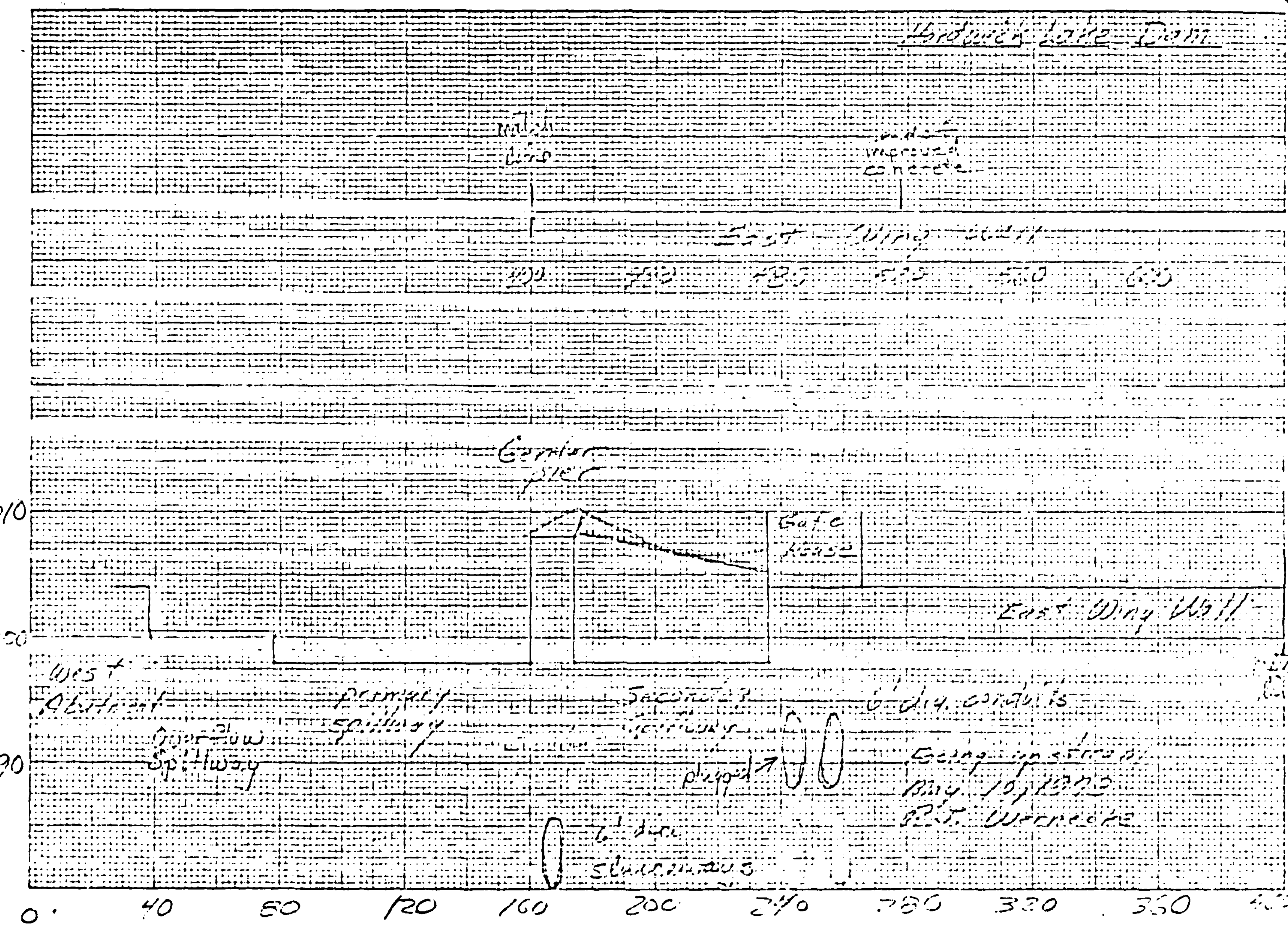
$Q_{100} = 13{,}000 \frac{29{,}300}{41{,}500} = 10{,}300$ cfs

spillway elevation is approximately 798.0

therefore stage at Dam would be

approximately 7 feet or 805 msl

No ~~great~~ substantial increase in stage would be experienced between Dam and RR bridge.



East Wing Wall
Gate House
Center pier
West Abutment
Overflow Spillway
6' dia. conduits
Going upstream
plugged
310
300
290
0
40
80
120
160
200
240
280
320
360
400

#	STREAM NAME & STATION	D.A.	Years of Record
-4900	Lamoille River at Johnson, VT	310	

DATE		PEAK OF DISCHARGE
NOV.	1927	~~[illegible]~~ 41,500
	1929	4,640
	1930	6,220
	1931	6,380
	1932	6,770
	1933	8,990
	1934	8,280
	1935	5,240
MAR. 18	1936	13,000
	1937	7,730
	1938	9,120
	1939	7,490
	1940	11,400
	1941	5,540
	1942	10,600
	1943	6,700
	1944	6,000
	1945	6,140
	1946	5,360
	1947	8,980
	1948	6,130
	1949	8,400
	1950	7,110

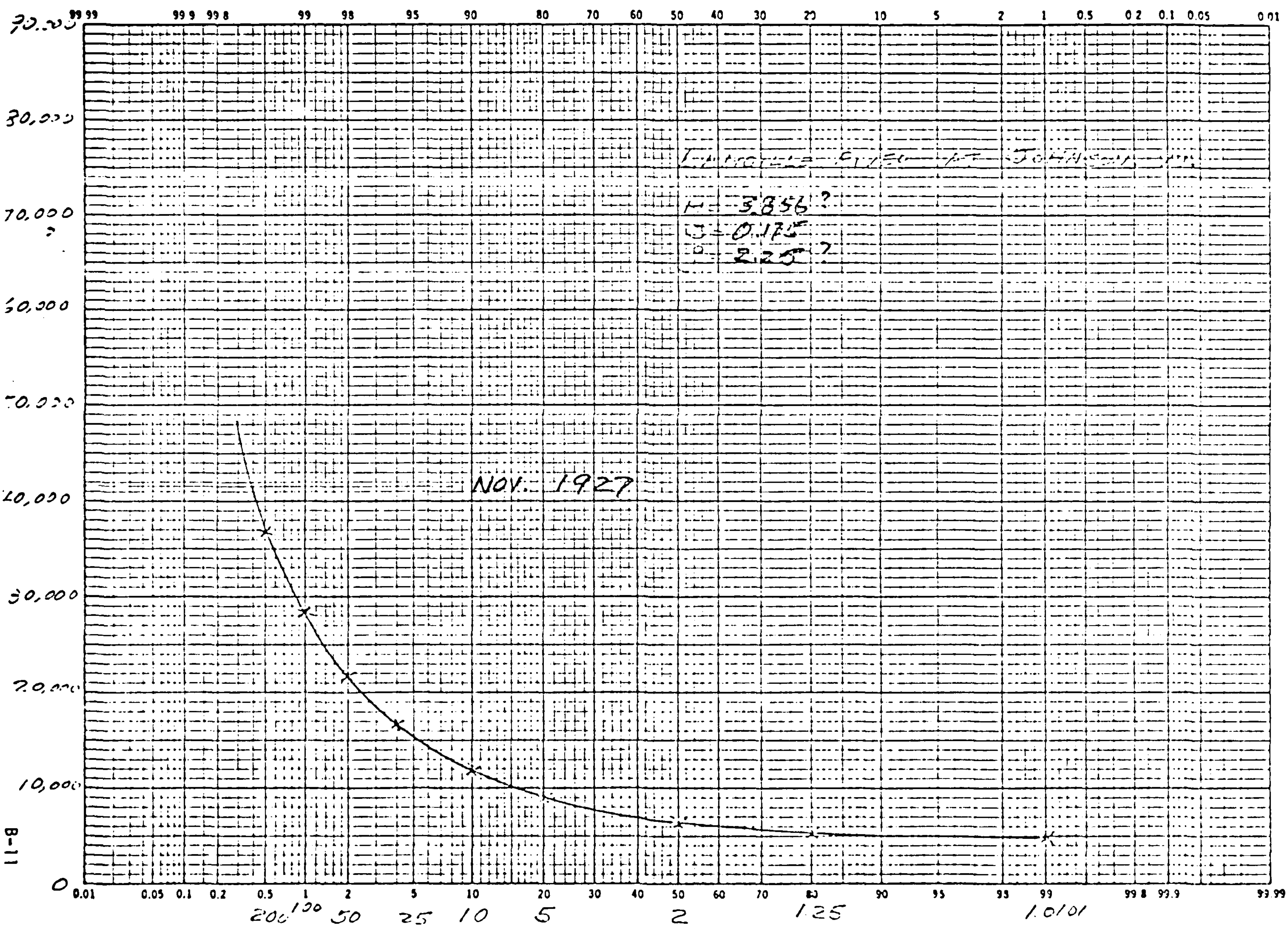
DATE		PEAK OF DISCHARGE
	1951	7,940
	1952	9,060
	1953	6,400
	1954	6,850
	1955	6,030
	1956	6,300
	1957	4,820
	1958	8,220
	1959	4,800
	1960	8,800
	1961	5,000
	1962	7,300
	1963	7,920
	1964	5470
	1965	2,760
	1966	4,910
	1967	5,910
MAR. 22	1968	5,860
MAY. 20	1969	9,220
APR. 25	1970	7,280
MAY. 4	1971	6920
MAY 5	1972	8,750*

* Provisional

PROBABILITY X 90 DIVISIONS

MADE IN U. S. A.

Johnson



STA #	STREAM NAME & STATION	D.A.	Years of Record
4-2925	Lamoille River at East Georgia	686	

DATE		PEAK OF DISCHARGES
Nov. 1927	(~~b~~ walevg?)	80,700
1929		
1930		10,420
1931		12,800
1932		12,000
1933		16,300
1934		10,600
1935		12,700
1936		23,200
1937		13,500
1938		20,200
1939		14,800
1940		22,300
1941		10,600
1942		17,400
1943		12,600
1944		11,800
1945		10,300
1946		11,900
1947		16,100
1948		7,300
1949		17,300
1950		11,100

DATE		PEAK OF DISCHARGE
	1951	10,900
	1952	12,900
	1953	11,800
	1954	12,500
	1955	13,000
	1956	11,000
	1957	8,500
	1958	15,100
	1959	10,000
	1960	14,300
	1961	9,220
	1962	13,000
	1963	14,300
	1964	11,500
	1965	7,350
	1966	8,440
	1967	12,100
Mar. 23	1968	11,000
May 21	1969	13,800
Apr. 18	1970	12,700
May 5	1971	12,200
May 5		

$M = 4.12117$

$S = 0.16310$

$g = 2.76515$

REPORT ON THE RENOVATED
HARDWICK LAKE DAM

Recent extensive repairs have improved the status of Hardwick Lake dam. This report on the work is made for the information of the Commission.

General

In a previous report (dated Oct. 27, 1949) the writer noted the unfavorable condition of Hardwick Lake dam. As indicated therein, complete rehabilitation was desired to restore its usefulness. Repairs were undertaken by the company, on its own initiative, in August - December, 1952. Since there was no change in crest level, Commission authorization was not solicited. The writer re-examined the structure on Dec. 17, 1952.

Pertinent information on the dam follows:

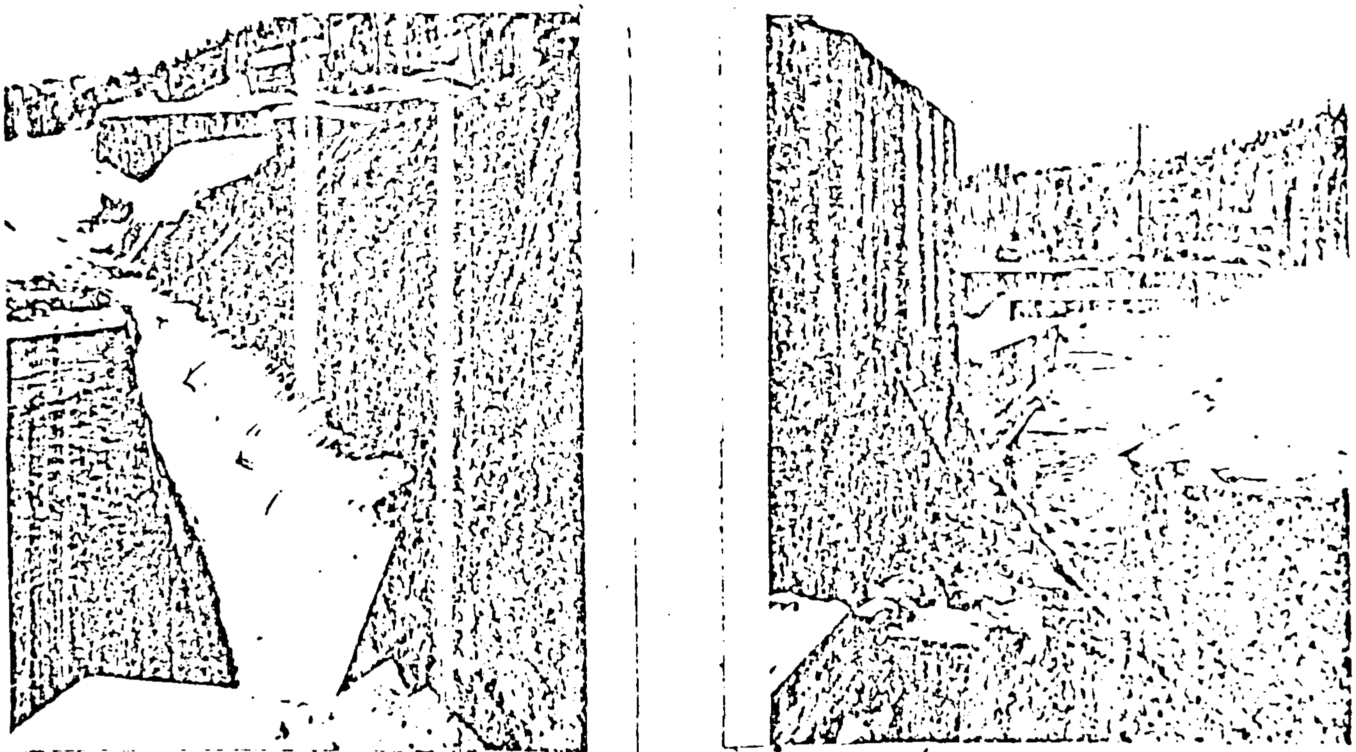
1. Owner & operator - Electric Dept.; Village of Hardwick
2. Location of dam - Lamoille R.; Town of Hardwick
3. Purpose of dam - Stream flow regulation
4. Surface area of lake - At full pond, about 200 acres.
5. Storage - Under existing silt conditions, the storage is estimated at 12,000,000 cu. ft.
6. Drainage area - 118 sq. mi.

Description of Dam

The main features of the rebuilt dam are indicated as follows:

Main spillway section - has the greatest depth, being located in the main river channel and on a ledge foundation. Shown in Fig. 1, it is about 82 ft. long and about 22 ft. high.

In cross-section; it has a vertical upstream face; a comparatively flat crest, 4 ft. wide; a sloping dowstream face flaring out to form a half-bucket 16 ft. below the spillway crest (at normal water line). Its base thickness is about 20 ft. Flashboards, 2.5 ft. high, are to be supported by 3" dia. pipe pins spaced at 3 ft. intervals.



~~upstream~~ face
downstream

~~downstream~~ face
upstream

FIG. 1 - Main spillway section with
West abutment in background

<u>West abutment</u> - As may be detected in Fig. 1, a 4 ft. thick wing wall extends 28 ft. from the spillway section to the abutment wall. It is 2.5 ft. higher than the spillway crest while the abutment wall is 6.5 ft. higher than the crest. The wing wall is intended to accommodate flows at higher pond levels.

Center sluiceway pier - is located at the east end of the main spillway section. Shown in Fig. 2, it measures about 14.5 ft. along the axis of the dam, 20 ft. wide at the top and 30 ft. wide at the base. It contains a 6 ft. dia. sluiceway and a manual-operated gate. The top of the pier is 10 ft. above spillway crest. A footbridge connects this pier with the east gate house.

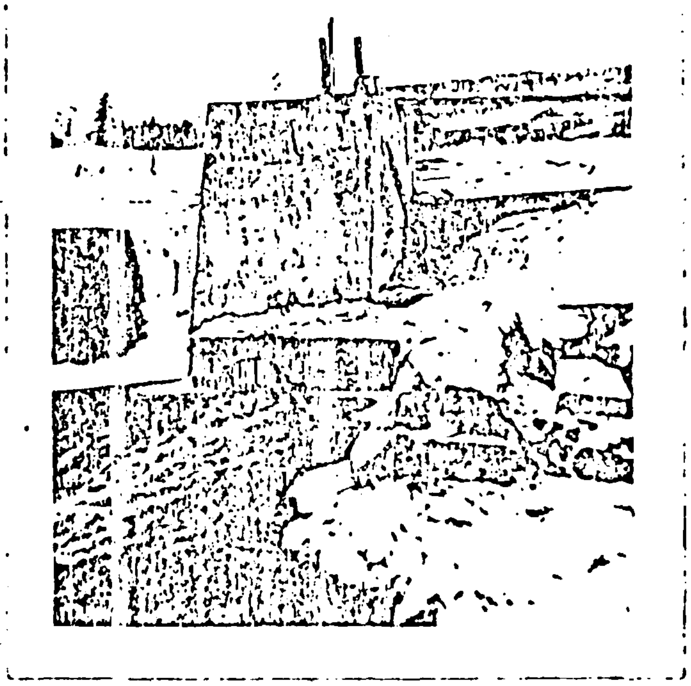


FIG. 2 - Center sluiceway pier

Additional spillway - is provided by fitting a crest to the ledge outcrop east of the center sluiceway pier. It is 62 ft. long and

at the same level and similiar in shape as the main spillway section. Also, the same flashboard arrangement will be used here.

<u>Regulating gate section</u> - is located at the east bank. Shown in Fig. 3, it is 25 ft. long, formerly provided with two outlet conduits. The west outlet has been plugged, leaving one 6 ft. dia. conduit 10 ft. down. Flow is regulated by a motor-operated lift gate. The concrete section is 6 ft. higher than the spillway crest. It is enclosed by a wooden structure. A training wall along the east bank directs the flow back into the river channel.

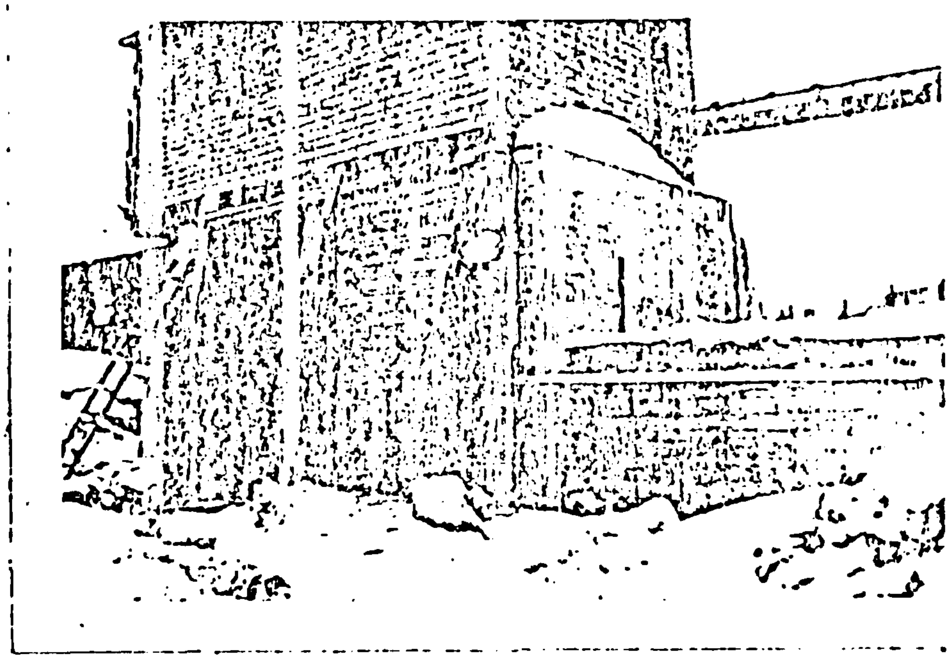


FIG. 3 - East regulating gate section

<u>East wing wall</u> - is a 300 ft. long non-overflow section extended into the earth bank. In cross-section, it has a 4 ft. top width, a vertical upstream face, and a sloping downstream face of about 6 on 1. Its top level is 6 ft. above spillway crest.

Comments on construction

The weather was particularly suited to construction work. It allowed for an early completion of the project.

In general, the job consisted of resurfacing the main portion of the dam, which includes all except the east wing wall. Disintegrated, poor concrete was trimmed down 8 to 12 inches and more. Reinforcement bars were dowelled into the old concrete for anchorage of the new concrete. New concrete was placed to the desired dimensions with the use of forms. The work was similar to that performed at Wolcott dam in 1948. Indications are that the same specifications were used.

An exceptional amount of new concrete was added. In particular, the base of the main spillway section was very badly eroded, requiring much filler. As observed at the time of visit, the concrete work shows an excellent finish (See photographs). It appears to have been placed in an orderly manner.

Other work performed included the installation of an improved conduit and gate at both the center pier and the regulating gate section.

No work was done on the east wing wall under this contract. This section is reasonably sound although it shows a surface condition on the downstream face. Plans are to back fill with earth on the downstream side to improve its appearance.

The contractor for the job was O. W. Miller Co. of Ludlow, Mass. The engineer was A. D. Bishop of Montpelier.

Review of design

As reconstructed the dam has sufficient thickness for stability for the usual operating conditions.

In the earlier report on the dam, mention was made of inadequate discharge capacity for a maximum flow of the November 1927 Flood size. This inadequacy remains since no appreciable change was made in spillway area. However, the height of dam and its location lessens the importance of this feature. About the only significance at floodtime would be the possible effect of backwater on the lower end of the village of Hardwick.

The proposed flashboard arrangement and operation at this dam is of some concern. As noted heretofore, the boards are to be the same height as on the previous crest but the pins, of the same size, will have a closer spacing by about 6". This tends towards a higher pond level and backwater before the boards go out to relieve the condition. Theoretically, failure of the boards is not likely until the pond level is at or above the top of the dam (end walls). Thus, the boards would be of a permanent nature, having an adverse effect on spillway capacity.

Operation with flashboards is to be the same as with flashboards on the old crest. The boards will be removed for the winter and spring thaw period. When boards are in place, pond level regulation will be by means of the two low level outlets. They could accommodate the ordinary flow of the river. A close control of pond level above flashboard height is required to minimize the backwater effect. With this method of operation, too much reliance is placed on the human element.

Conclusions

Hardwick Lake dam is now a greatly improved structure. The method of repairs was in accordance with accepted engineering practice.

An objectional feature is the proposed flashboard installation. A more flexible arrangement with smaller diameter pins or a tipping section would better suit the conditions.

By Stephen H. Haybrook
STEPHEN H. HAYBROOK
HYDRAULIC ENGINEER

Public Service Commission
January 28, 1953

STATE OF VERMONT
PUBLIC SERVICE COMMISSION

Electric-Utility Dams

1. Name of Dam: Hardwick

2. Owner of Dam: Village of Hardwick

3. Located in What Town: Hardwick

4. Is the Dam in Use: yes

5. Name of Lake, Pond, River, Brook, Creek, Etc., on Which Located:
Hardwick Lake

6. Material Used in Construction of the Dam:
Concrete

7. Purpose for Which Dam is Used:
Storage

8. Is Dam Attended or Unattended:
yes

9. Approximate Surface Area of the Body of Water Impounded by Dam:
200 acres

10. Approximate Volume of Water, in Cubic Feet, Impounded by Dam When in Full Use:
90,510,000 gals, 12,06[illegible] FT^3

11. Regulations Governing the Operation of the Dam:
None

12. Remarks:

Of not too much value since the 1927 flood

Utility: Village of Hardwick

Signed: [illegible signature]
(Title)

Vt. Hist. ; Elect.
Dams ; Dam

REPORT ON HARDWICK LAKE DAM

Hardwick Lake dam, owned and operated by the Electric Department of the village of Hardwick, Vermont, was inspected by the writer in conjunction with the study of dams in Vermont. Its dilapidated condition is brought to the attention of the Public Service Commission via this report.

General:

The dam at Hardwick Lake is located in the course of the Lamoille River in the town of Hardwick. It creates a reservoir of about 200 acres lying mostly in the valley of Alder brook. Under present silt conditions the storage is estimated at 12 million cubic feet. The drainage area at the site is 118 square mile.

Description of Dam:

This dam, a concrete structure built on ledge rock in one continuous line (about 600 feet) across the valley, is made up with the following sections (proceeding from the west abutment to the east abutment):

A composite spillway section 120 feet long, consisting of a 26 ft. length of laid-up granite stone at the abutment and remainder of concrete. This is the maximum section of the dam, reaching a depth of about 20 feet. It has a vertical upstream face, a crest width of about 4 feet, a sloping downstream face of about 2 on 1, and a base width of about 15 feet. Two feet of flashboards are provided on the crest.

Next is the sluiceway pier whose top is 9 ft. higher than the spillway crest. It is a concrete block measuring about 18 ft. by 12 ft. and containing an 8 ft. diameter steel sluice pipe at its lowest elevation. A manually operated wooden slide gate controls the flow through the pipe.

More spillway is provided in the next section which is 60 ft. long. It has a crest width of about 7 ft. A rock outcrop limits the maximum depth of this section to about 3 ft. Flashboards, corresponding to those on the main spillway section, are built-up on the crest.

Adjacent to this spillway section is an outlet structure containing two 7 ft. diameter discharge pipes located 10 ft. below the top of the dam. Wooden slide gates for both pipes are operated from a wooden building directly above. A concrete training wall just downstream from this outlet structure retains the east bank of the river channel. Also, a 3 ft. footbridge is provided between the gate house and the sluiceway pier.

To complete the dam is a 370 ft. concrete retaining wall which serves as a non-overflow section with its top level 6 feet above spillway crest. This section has a 4 ft. top width, a vertical upstream face and a downstream face sloping about 6 on 1. The visible portion of this section is about 6 ft. in maximum height.

Flashboards provided on the crest are supported by 3 inch diameter pipe lengths.

Condition of the Dam:

The general condition of the dam is indicated in the accompanying photographs. From these it can be seen that the dam is gradually losing its structural integrity.

Figure 1 shows the condition of the main spillway section. The finished surface was a reinforced layer of mortar concrete applied after the original surface has been scoured away. Note that this added surface layer is now practically all gone. The process for the surface disintegration is shown in Figure 2. The poorer quality concrete under the surface layer is eaten away first. After the surface layer is undermined sufficiently it breaks away either by its own weight or the weight of flowing water.

The progress of erosion in the sluiceway pier is indicated in Figure 3. Note that its base is well eaten away.

Not only the main spillway section but the whole dam was re-surfaced with a mortar concrete. The whole downstream face appears in a similiar condition, rough and scaly. On the other hand the upstream face has stood up well.

Some leakage was observed on the spillway side of the outlet structure but was not considered serious. The training wall was found badly scoured along its base in a few places.

Most of the gate timbers were rotted and some were broken off, indicating a need for replacement. The trash rack at the intake was either omitted or destroyed, thus permitting debris to accumulate at the gates.

The pond behind the dam has accumulated much silt. From an original storage volume of about 80 million cubic feet the capacity has reduced to about 12 million cubic feet. From Figure 1, note the small body of water for a level 5 feet below the crest.

General Comments:

This dam was visited by the writer at different times, the last being October 25, 1949. Its behavior was observed under various water conditions. In Figure 4, the spillway is discharging a typical spring thaw.

The writer discussed the dam with Mr. Guy W. Larrabee, superintendant of the company's plants. According to Mr. Larrabee, the structure was partially wrecked in the November, 1927 flood and has not been of too much value since, particularly under the present silt conditions. However, the owner plans to completely rehabilitate the structure as soon as time and money permit. The company has recently restored its Greensboro and Wolcott dams.

The original dam at Hardwick Lake was constructed of poor quality concrete which made it easily affected by flowing water and by freezing and thawing. An attempt was made to restore the surface in 1930 when gunite concrete (mortar concrete applied as a spray under pressure) was used. It is evident that the workmanship was inferior.

Below the dam, the Lamoille River passes through relatively flat, open country before reaching Wolcott dam 5 miles downstream and then a center of population. The flood damage potential, should the dam fail and release its storage, would not be as great as in the case of some other dams of this size.

Conclusions:

In its present condition, Hardwick Lake dam is susceptible to progressive failure. Although the dam may be stable at this time, its rate of disintegration, because of poor construction materials, gradually reduces its mass to the point of incipient failure. If the dam is to be maintained then some rehabilitation work would be desirable.

As for its discharge capacity, the spillway cannot adequately accommodate flows equivalent to or greater than the November, 1927 flood.

Stephen H. Haybrook

STEPHEN H. HAYBROOK
HYDRAULIC ENGINEER

Public Service Commission
Montpelier, Vermont
October 27, 1949

Report No. 80

Fig. 1. - Eroded condition of downstream face, main spillway section of Hardwick Lake Dam

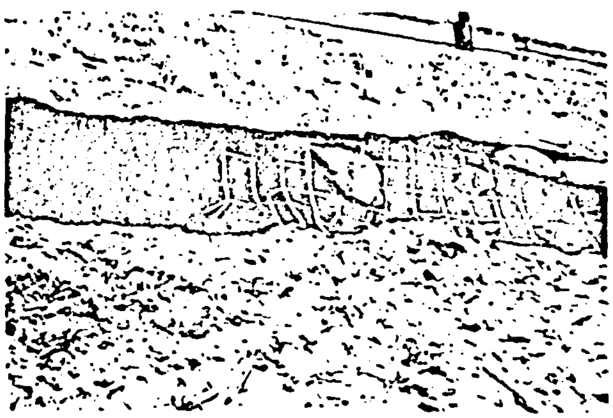


Fig. 2. - A close-up of the erosion conditions, same section as in Fig. 1.

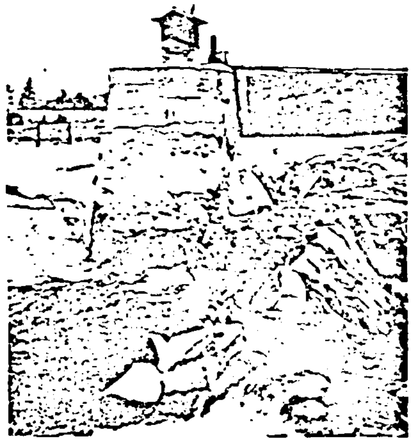


Fig. 3. - Eroded condition of the sluiceway pier,

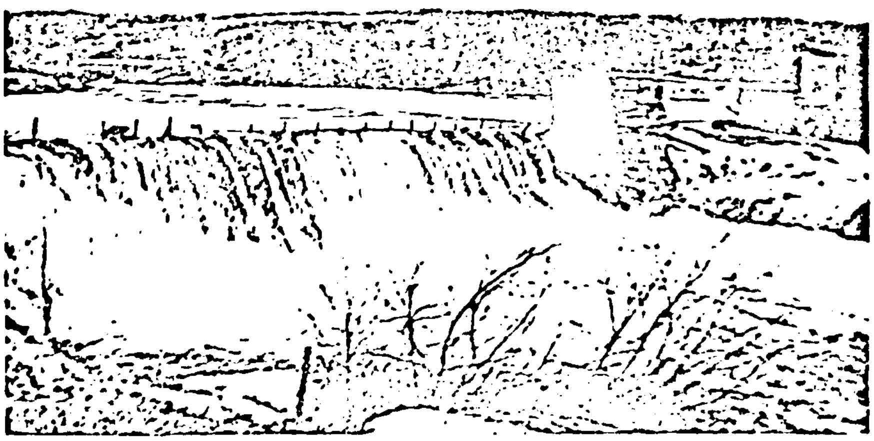
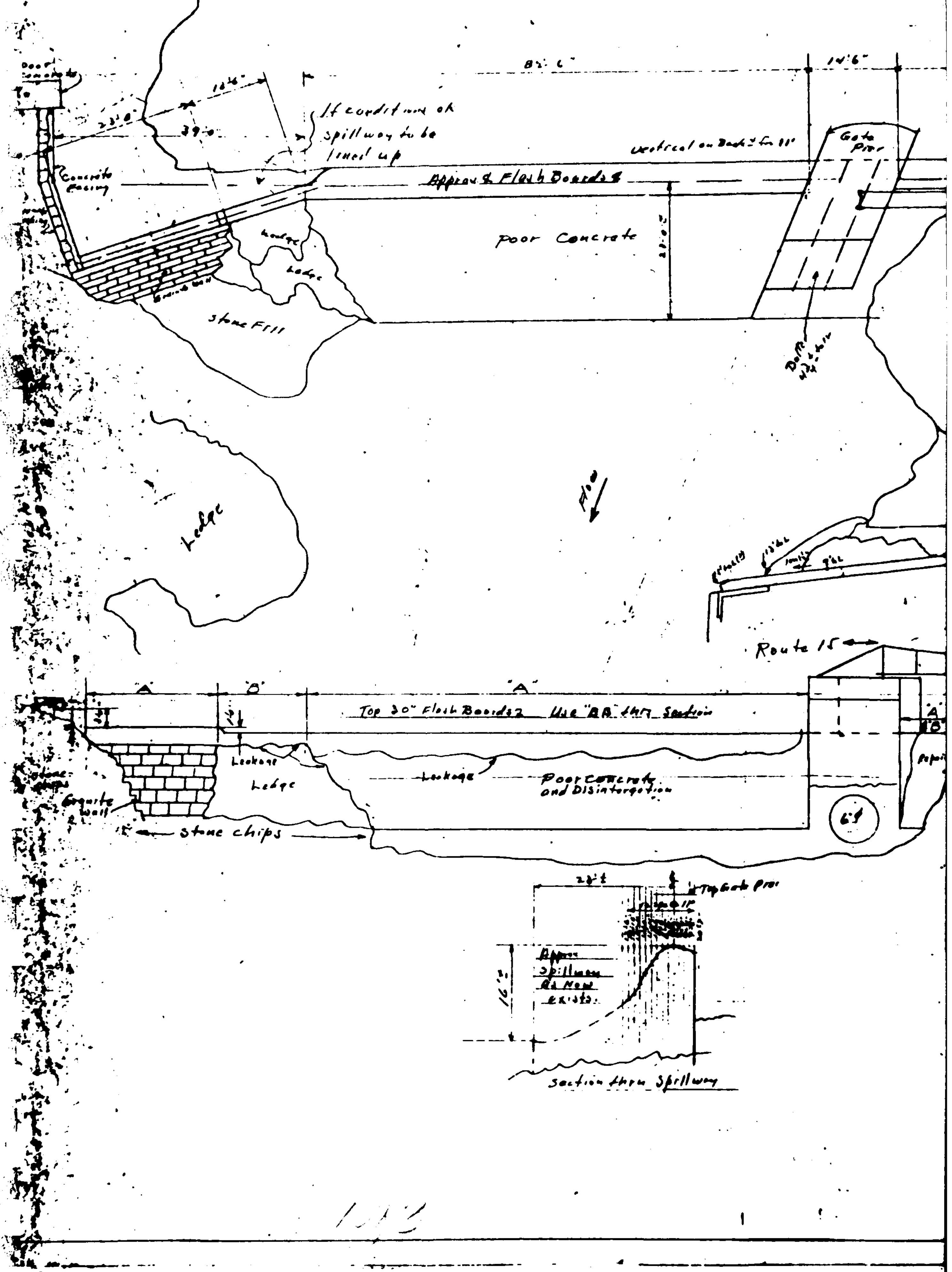
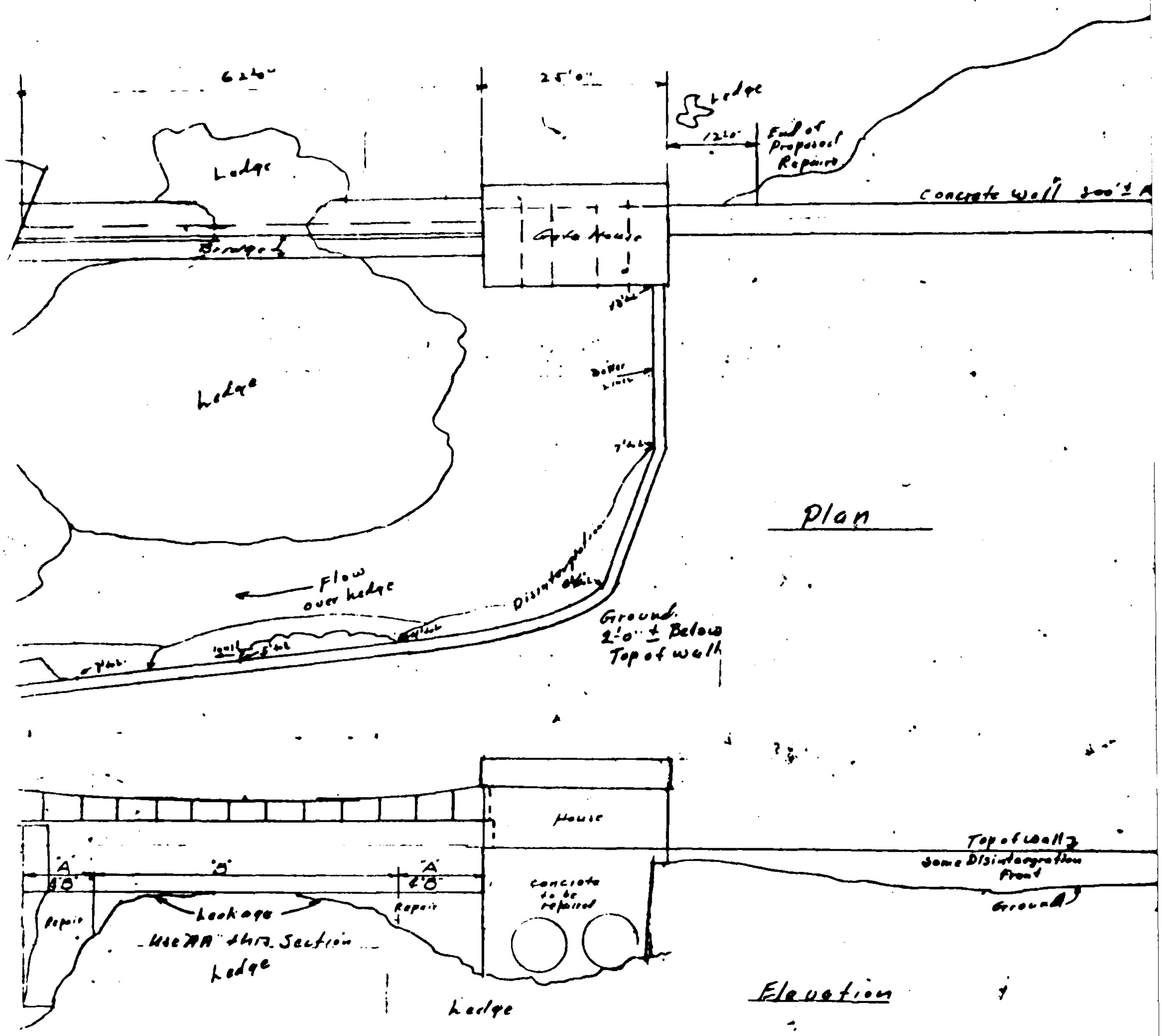


Fig. 4. - Spillway discharging a spring thaw.


84'-6"
14'-6"
39'-0"
If condition ok spillway to be lined up
Concrete Facing
Gate Pier
Approx ℄ Flash Boards ℄
poor Concrete
Ledge
Ledge
Stone Fill
Flow
Ledge
Route 15
"A"
"B"
"A"
Top 30" Flash Boards ℄ Use "BB" thru Section
Leakage
Ledge
Leakage
Poor Concrete and Disintegration
Granite Wall
stone chips
Top Gate Pier
16'
Approx Spillway As Now exists.
Section thru Spillway

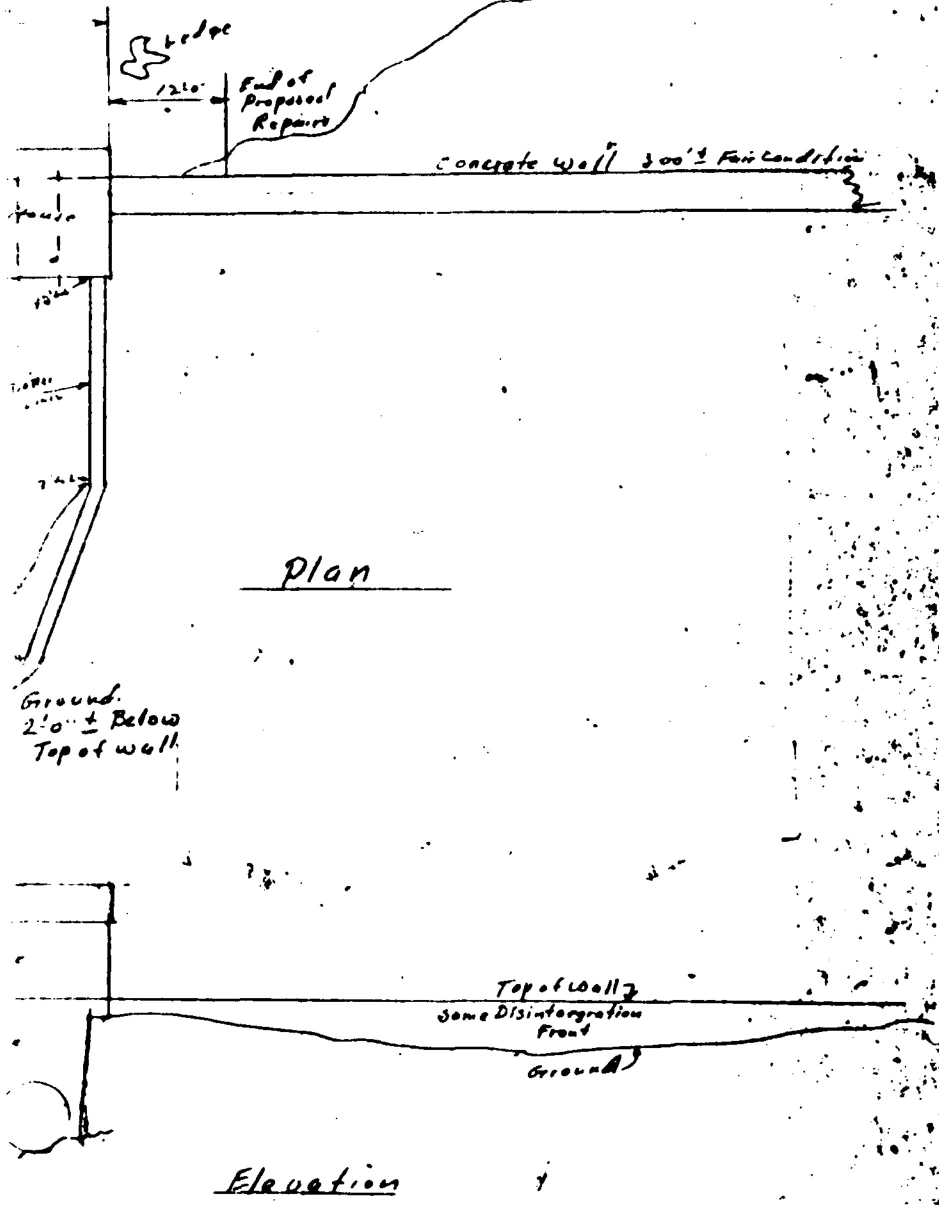


Scale 1" = 10'-0"

Plan of
Hardwick Vi
Storage Rese
at
Junction Route
15 and 12B
Hardwick Va

Drawn by A.D.T.
June 13 1957
NOT TO SCALE

203

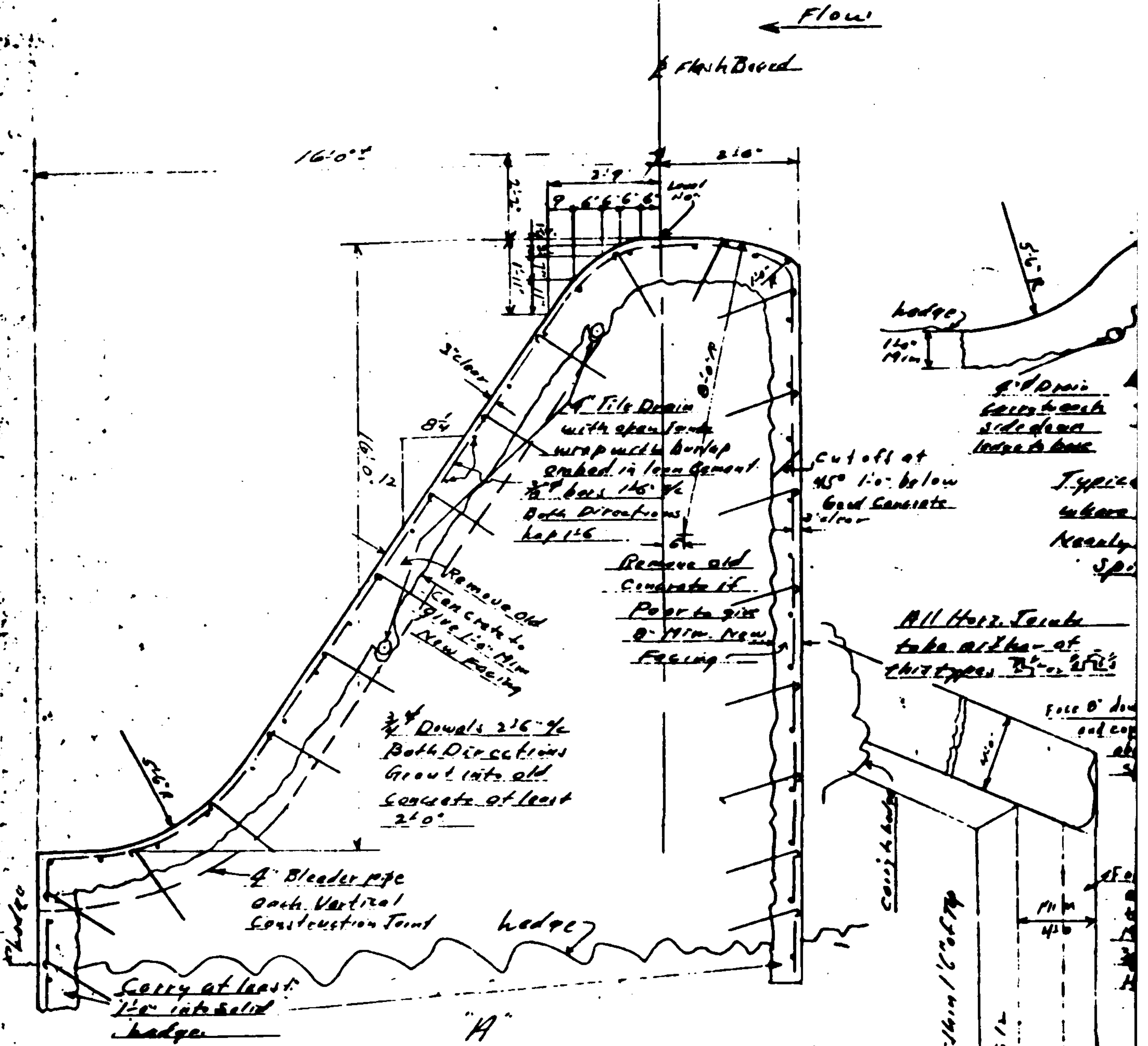


Plan of
Hardwick Village
Storage Reservoir
at
Junction Routes
15 and 12B
Hardwick Vermont

Drawn by O.D. Bishop
June 13, 1957

NOT TO SCALE

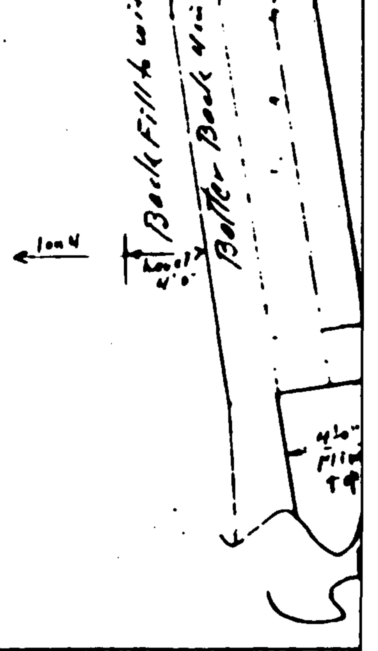
Sheet 1 of

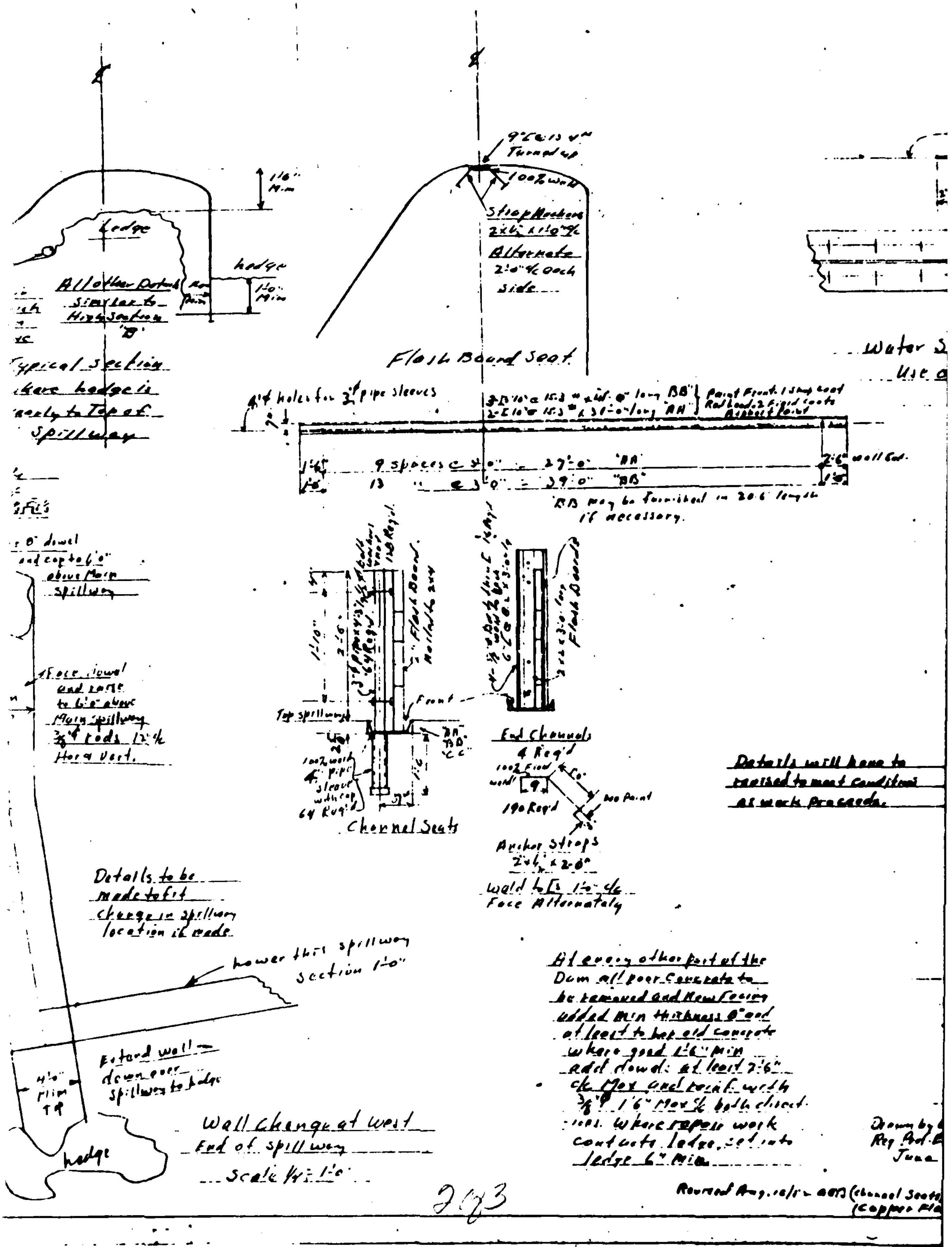


"A"

Typical Section
Thru High Spillway
Scale 1/4" = 1'-0"

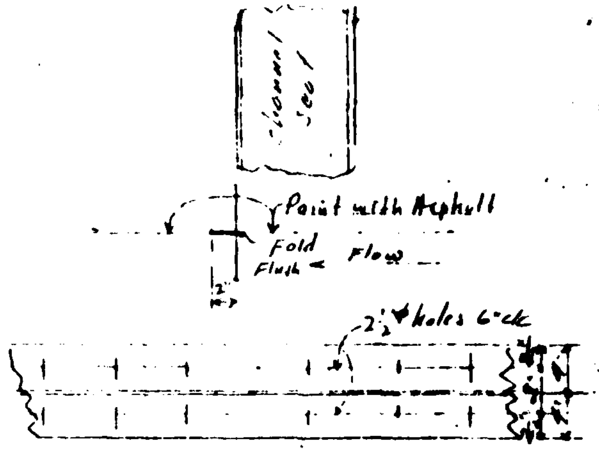
Carry this Section across Granite Section dowelling to Granite Blocks lowering Spillway to this Elev. and adding drains 4" at inside corner every other step. Drains to slope toward Main Section and downward at ledge where spillway in all cases extends to side Ledge carry New work at least 1'-0" into Solid Ledge shoulder as okey and add Drains.



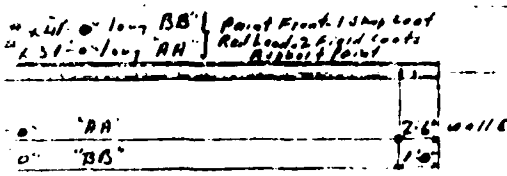


9" C 13.4" Turned up
100% weld
Strap Anchors 2x¼ x 1'0" ⅝
Alternate 2'0" ⅝ each side
Flash Board Seat
1'6" Min
Ledge
Ledge
1'0" Min
All other Details Similar to High Section "B"
Typical Section where Ledge is nearly to Top of Spillway
4" holes for 3" pipe sleeves
9 spaces @ 3'0" = 27'0" "AA"
13 @ 3'0" = 39'0" "BB"
BB may be furnished in 20'6" lengths if necessary.
2'6" wall Cut.
dowel and cap to 6'0" above Main Spillway
Face dowel and same to 6'0" above Main Spillway
⅝" rods 1'2" ⅝ Hor & Vert.
Flash Board Nailed to 2x4
Front
Top spillway
100% weld
4" pipe sleeve with cap 64 Req'd
Channel Seats
End Channels 4 Req'd
190 Req'd
Anchor Straps 2x¼ x 2'0"
Weld to [1'0" ⅝ Face Alternately
Flash Boards
Details will have to revised to meet conditions as work proceeds.
Details to be made to fit change in spillway location if made.
Lower this spillway section 1'0"
Extend wall down over spillway to ledge
4'0" Min T.P.
Ledge
Wall Change at West End of Spillway
Scale ¼" = 1'0"
At every other part of the Dam all poor Concrete to be removed and New Facing added Min thickness 8" and at least to top old concrete where good 1'6" min add dowels at least 2'6" c/c Max and reinf. with ⅝" 1'6" Max ⅝ both directions. Where repair work contacts ledge, set into ledge 6" Min.
Water S
Use
Drawn by
Reg. Prof. E
June
Revised Aug. 10/1 ... (Channel Seats) (Copper Fla

293



Water Stop Flashing
Use only where slopes off foot
3 Req'd about 6'-0" long



...s may be furnished in 20' lengths if necessary.

...ols

No Point

...ops

-6"

1'-0" c/c

...mately

Details will have to revised to meet conditions as work proceeds.

...l every other part of the ...m all poor Concrete to ... removed and New Facing ...dded Min thickness 8" and ... least to lap old Concrete where good 1'-6" min add dowels at least 2'-6" c/c Max and reinf. with 3/8" φ 1'-6" Max c/c both directions. Where repair work contacts ledge, set into ledge 6" Min.

Details for Repair
Hardwick Village
Storage Reservoir
at
Junction Routes
15 and 12B
Hardwick Vermont

Drawn by A D T Smith
Reg Prof Eng #1 Vt.
June 21/5-

Jackson Dam

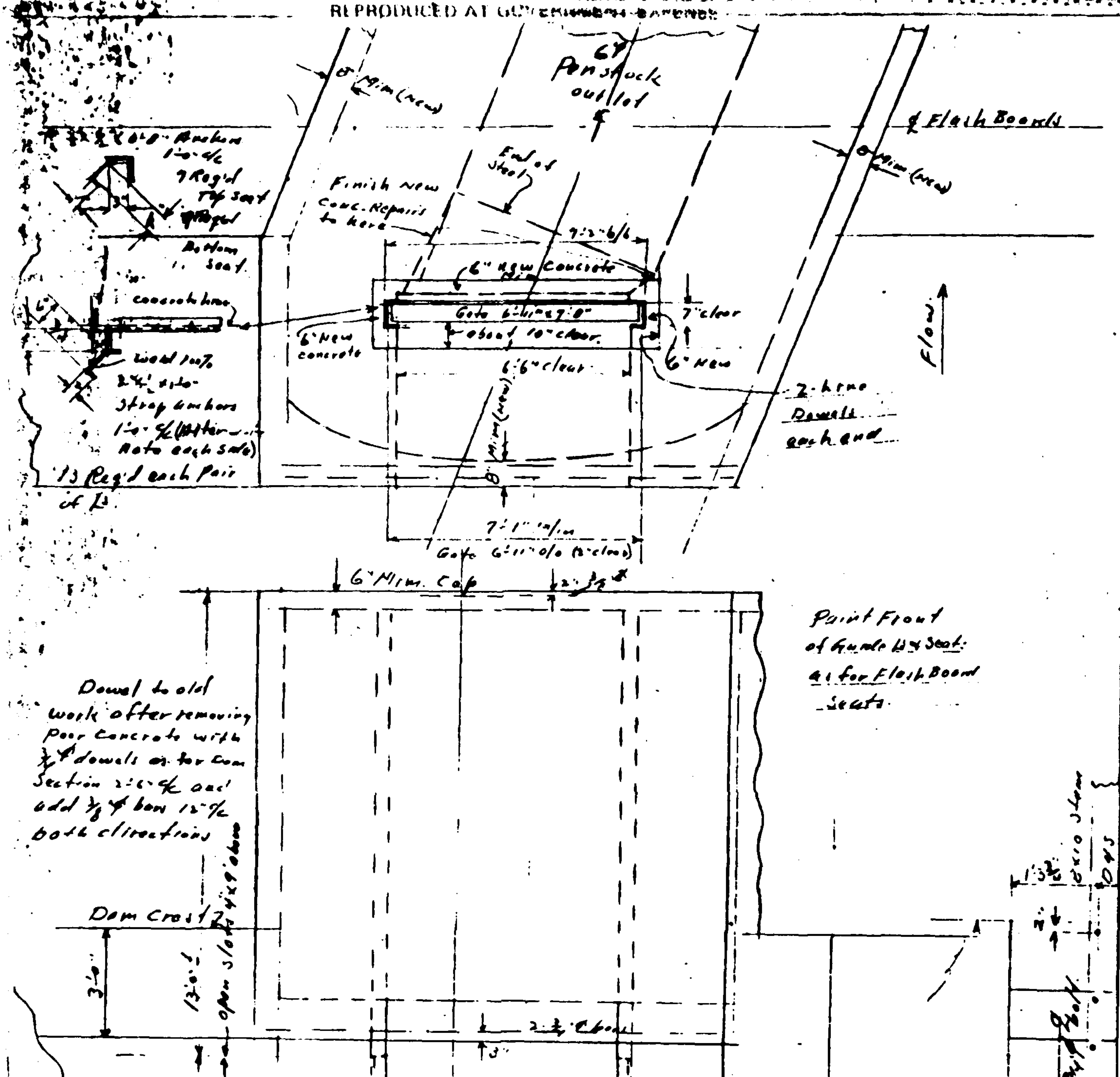
Revised Aug. 16/5- ADTS (Channel Seats) (Copper Flashing)

Sheet 2 of ...

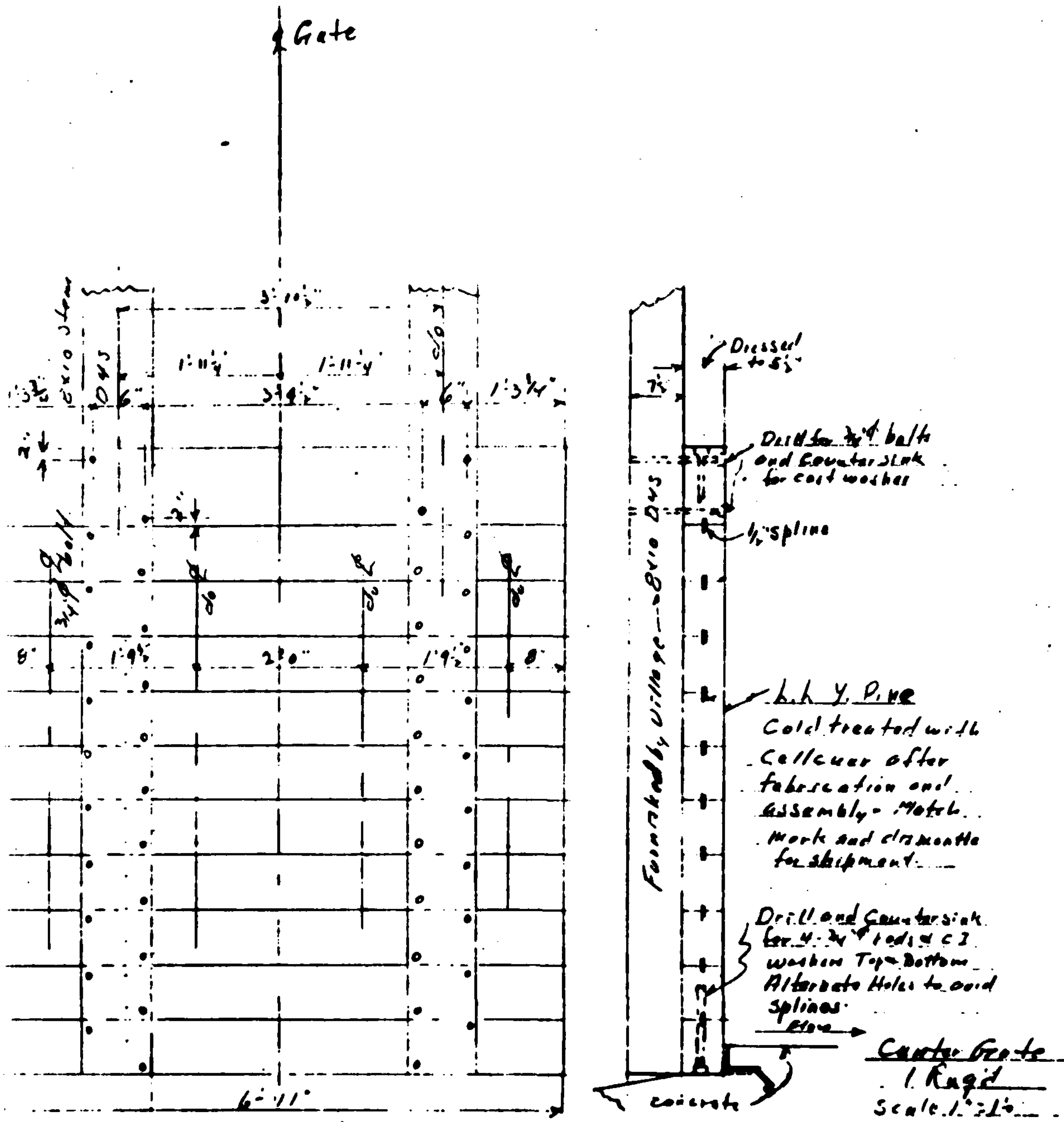
NOT TO SCALE

B-30

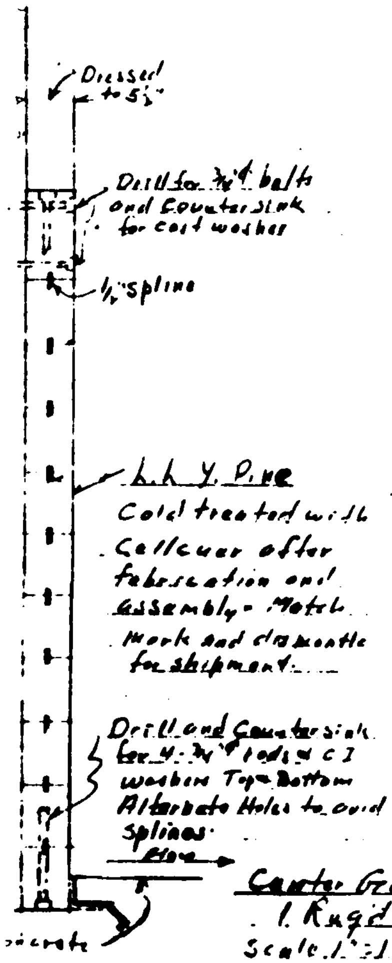
393



6'
Penstock outlet
℄ Flash Boards
Finish New Conc. Repairs to here
End of Steel
6" New Concrete
Gate 6'-11" x 9'-0"
about 10" clear
7" clear
6" New concrete
6" New
6'-6" clear
2-1" Dowels each end
Flow
7'-1"
Gate 6'-11" o/o
Bottom Seat
concrete line
Strap anchors
13 Req'd each Pair of Ls
6" Min. Cap
Paint Front of Guide Ls & Seat as for Flash Board Seats
Dowel to old work after removing Poor Concrete with 3/4" dowels as for Conc Section 2'-0" c/c and add 3/8" bars 15" c/c both directions
Dam Crest
3'-0"
Top of Guides
Carry Concrete to ledge
ledge
Buttress
Buttress
2Ls 4x4x3/8x12'-0"
1L 4x4x1/2x6'-6" Top Seat
1L 4x4x1/2x6'-6" Bottom Seat
Scale 1/4" = 1'-0"
7'-8"
8"


Gate
3'-10½"
1'-11¼"
1'-11¼"
3'-4½"
6"
6"
1'-3¼"
1'-9½"
2'-0"
1'-9½"
8"
8"
6'-11"
Dressed to 5½"
Drill for ¾" bolts and Countersink for cast washer
½" spline
L.L.Y. Pine
Cold treated with Cellcure after fabrication and assembly - Match Mark and dismantle for shipment.
Drill and Countersink for 4-¾" rods & C.I. washers Top & Bottom. Alternate Holes to avoid Splines.
Flow
concrete
Center Gate
1 Req'd
Scale 1" = 1'-0"

NOT TO



Center Gate
1 Reqd
Scale 1" = 1'0"

Details of
Center Gate
Jackson Dam
Jewel 9 + 15 w 12B
Hardwick Village
Vermont

Drawing H. D. Bishop
Aug 9 1933

NOT TO SCALE

Sheet 3 of

APPENDIX C

DETAIL PHOTOGRAPHS

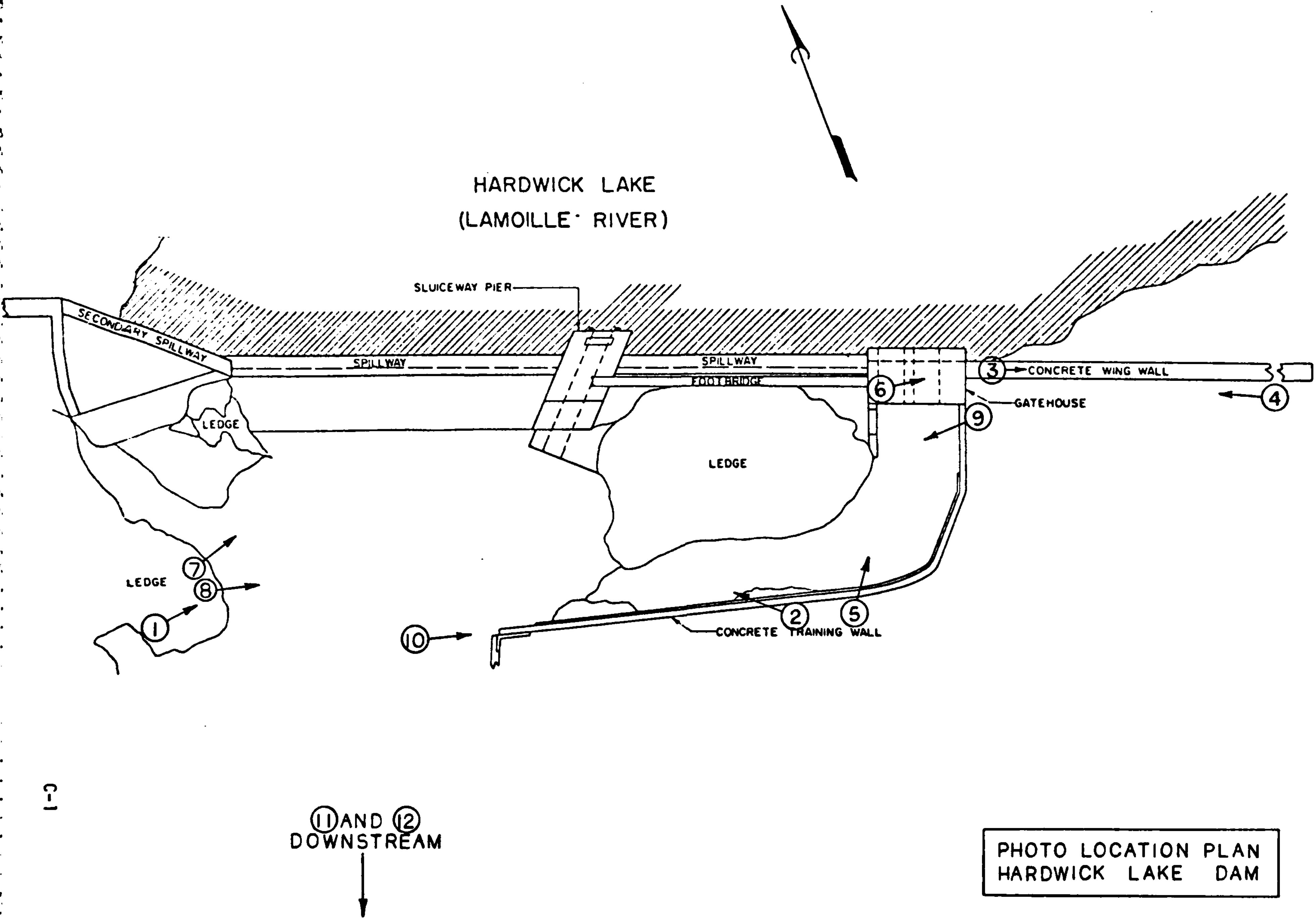


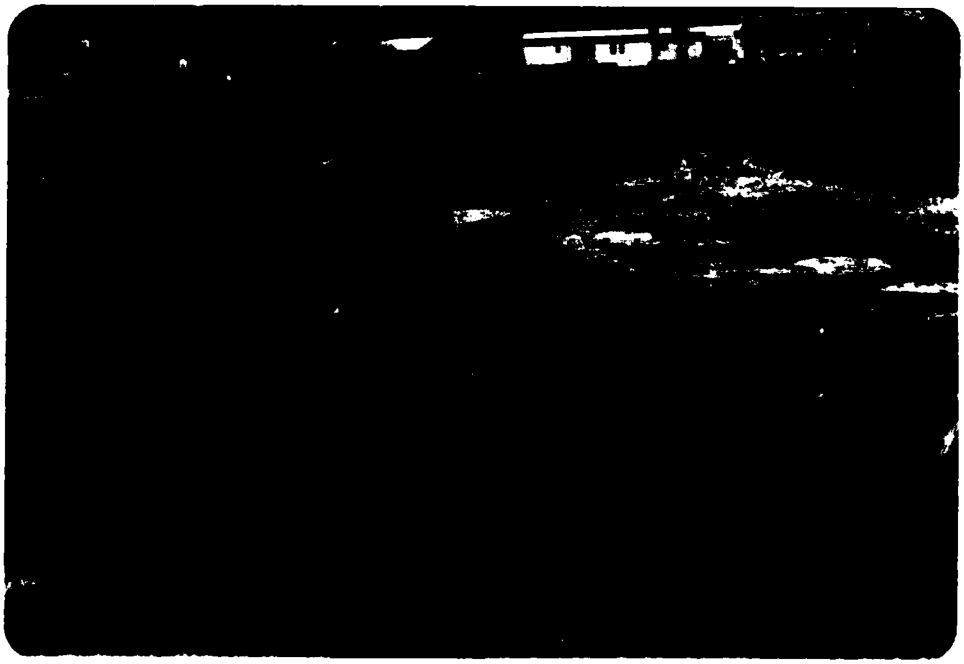
PHOTO LOCATION PLAN
HARDWICK LAKE DAM

(1) Spillway and Central Pier Containing Low-Level Pond Drain

(2) Spillway (Right) and Secondary Spillway at Right Abutment. Exposed Bedrock Evident Between Spillways and In Foreground.

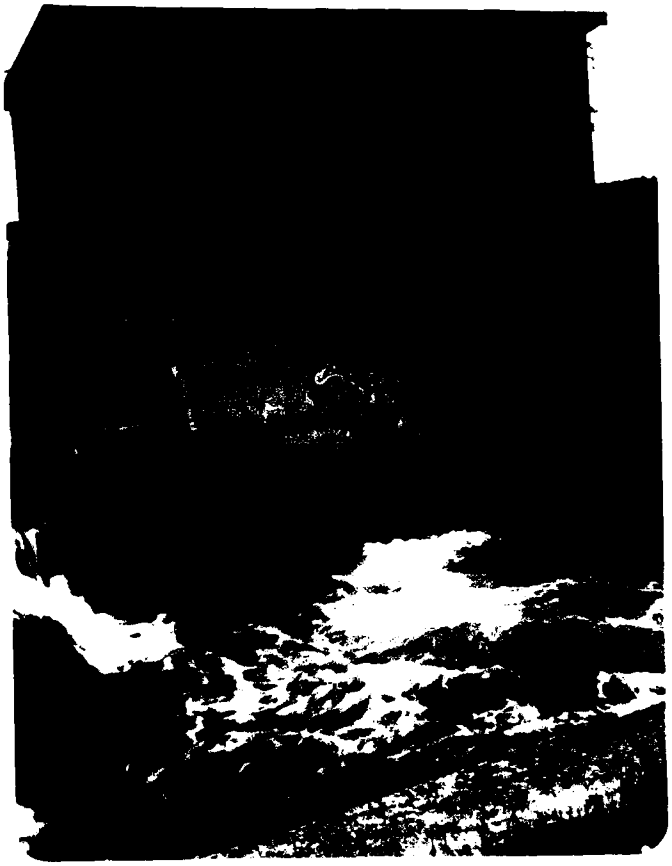
U.S. ARMY ENGINEER DIV, NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS	NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS	Hardwick Lake Dam Hardwick, Vermont VT 00186 May 6, 1980
JAMES W. SEWALL COMPANY CONSULTANTS OLD TOWN, MAINE		C-2

(3) Non-Overflow Wing Wall Extending East from Left Abutment of Dam



(4) Extensive Spalling, Downstream Face of Wing Wall

U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS	NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS	Hardwick Lake Dam Hardwick, Vermont VT 00186 May 6, 1980
JAMES W. SEWALL COMPANY CONSULTANTS OLD TOWN, MAINE		C-3

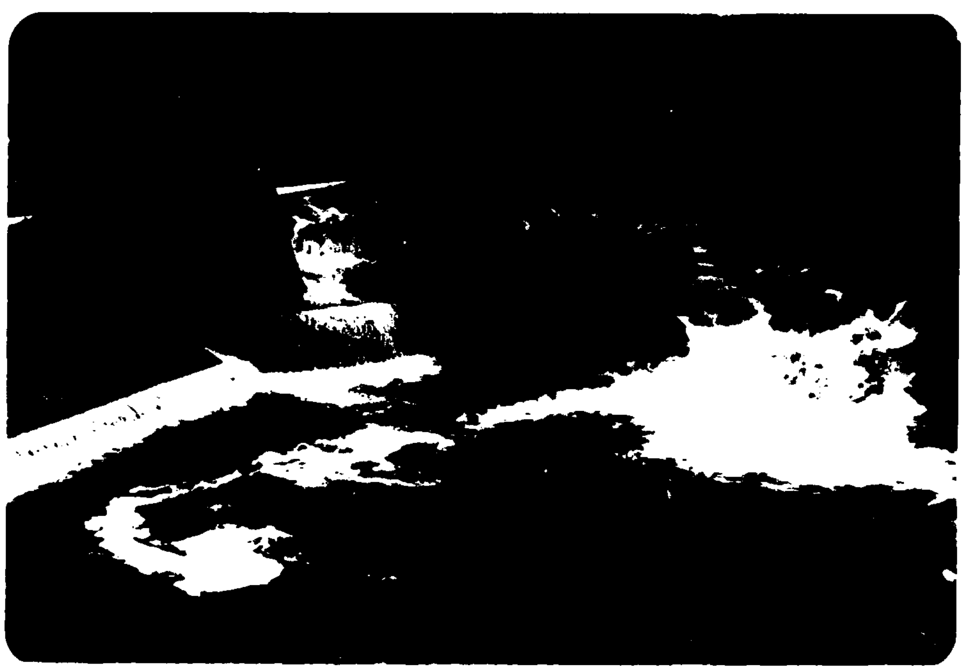


(5) Gate Structure at Left Abutment

(6) Left Outlet Gate Operating Mechanism

U.S. ARMY ENGINEER DIV, NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS	NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS	Hardwick Lake Dam Hardwick, Vermont VT 00186 May 6, 1980
JAMES W. SEWALL COMPANY CONSULTANTS OLD TOWN, MAINE		C-4

(7) Spillway and Reservoir Pool



(8) Discharge Channel, With Concrete Training Wall at Right Background

U.S. ARMY ENGINEER DIV, NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS	NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS	Hardwick Lake Dam Hardwick, Vermont VT 00186 May 6, 1980
JAMES W. SEWALL COMPANY CONSULTANTS OLD TOWN, MAINE		C-5

(9) Left Discharge Channel From Gate Structure. Training Wall and Jackson Bridge in Background.

(10) Eroded Section of Training Wall at Junction with Bridge Wing Wall

U.S. ARMY ENGINEER DIV, NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS	NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS	Hardwick Lake Dam Hardwick, Vermont VT 00186 May 6, 1980
JAMES W. SEWALL COMPANY CONSULTANTS OLD TOWN, MAINE		C-6

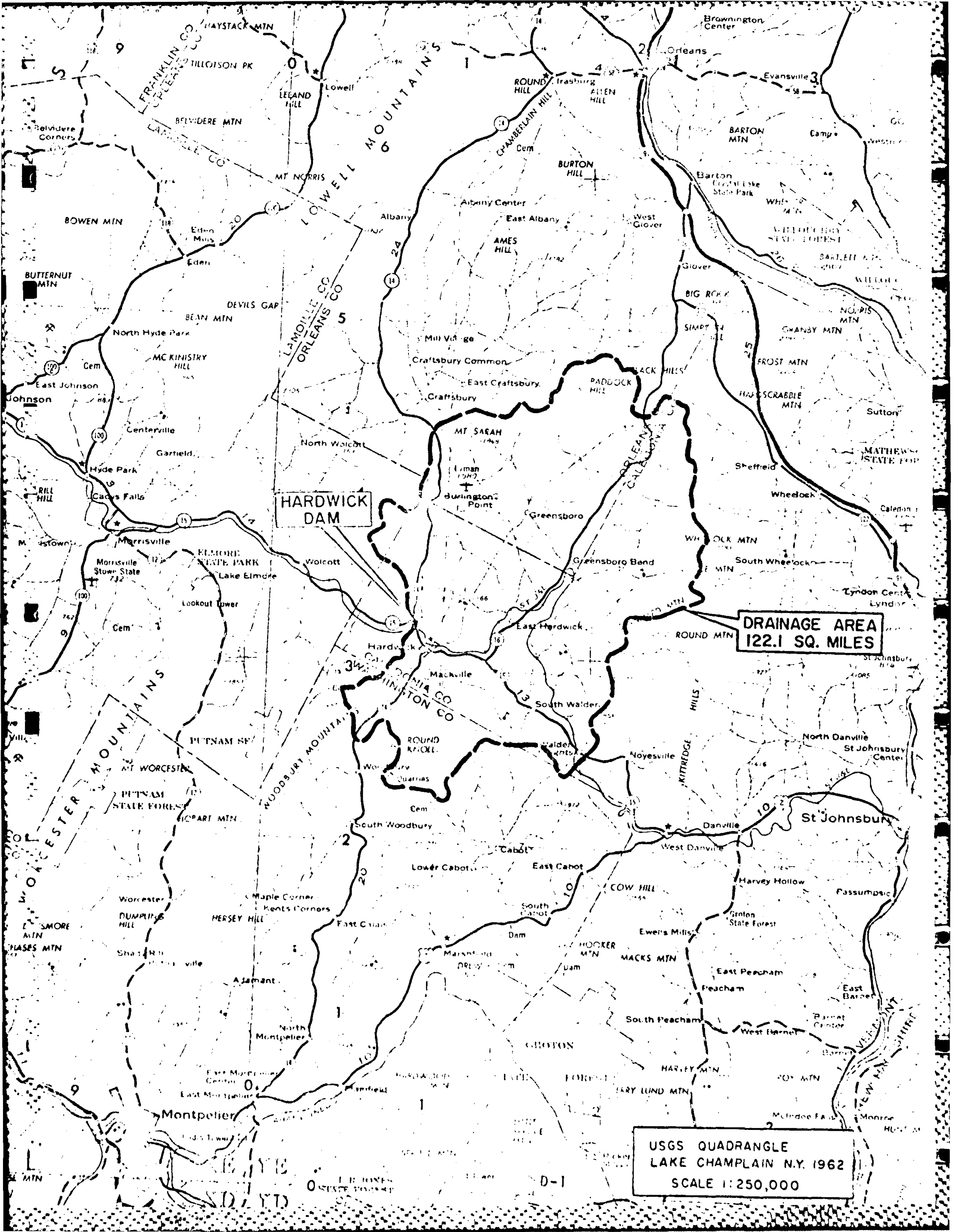
(11) Covered Lamoille Valley Railroad Bridge

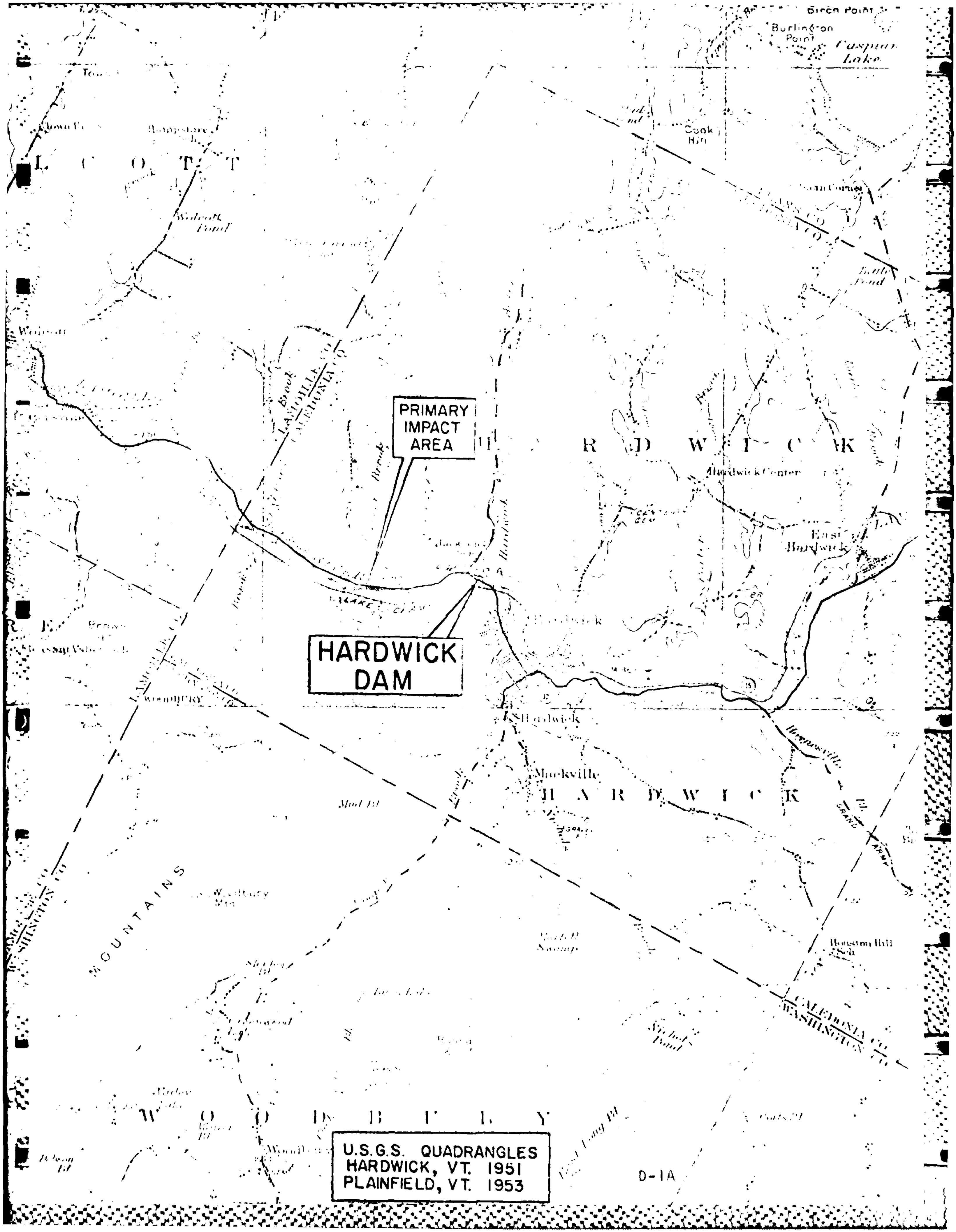
(12) Route 15 Crossing, Approximately 3.3 Miles Below Dam

U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS	NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS	Hardwick Lake Dam Hardwick, Vermont VT 00186 May 6, 1980
JAMES W. SEWALL COMPANY CONSULTANTS OLD TOWN, MAINE		C-7

APPENDIX D

HYDRAULIC/HYDROLOGIC COMPUTATIONS


HARDWICK DAM
DRAINAGE AREA 122.1 SQ. MILES
USGS QUADRANGLE
LAKE CHAMPLAIN N.Y. 1962
SCALE 1:250,000
LOWELL MOUNTAINS
WORCESTER MOUNTAINS
WOODBURY MOUNTAINS
HAYSTACK MTN
TILLOTSON PK
BELVIDERE MTN
MT NORRIS
BOWEN MTN
BUTTERNUT MTN
DEVILS GAP
BEAN MTN
MC KINISTRY HILL
BARTON MTN
BURTON HILL
AMES HILL
BIG ROCK
GRANBY MTN
FROST MTN
PADDOCK HILL
MT SARAH
WHEELOCK MTN
ROUND MTN
ROUND KNOLL
MT WORCESTER
PUTNAM STATE FOREST
HOGBACK MTN
COW HILL
HOOKER MTN
MACKS MTN
HARVEY MTN
FRANKLIN CO
ORLEANS CO
LAMOILLE CO
CALEDONIA CO
WASHINGTON CO
Lowell
Irasburg
Orleans
Evansville
Barton
Glover
Albany
Albany Center
East Albany
West Glover
Eden
Eden Mills
North Hyde Park
East Johnson
Johnson
Centerville
Garfield
Hyde Park
Cadys Falls
Morrisville
Lake Elmore
Lookout Tower
Wolcott
North Wolcott
Mill Village
Craftsbury Common
East Craftsbury
Craftsbury
Greensboro
Greensboro Bend
East Hardwick
Hardwick
Mackville
South Walden
Walden
Noyesville
Sheffield
Wheelock
South Wheelock
Sutton
North Danville
St Johnsbury Center
St Johnsbury
Danville
West Danville
South Woodbury
Cabot
Lower Cabot
East Cabot
Harvey Hollow
Passumpsic
Worcester
Maple Corner
Kents Corners
South Cabot
Marshfield
Ewells Mills
East Peacham
Peacham
South Peacham
West Barnet
East Barnet
Adamant
North Montpelier
East Montpelier
Montpelier
Plainfield
GROTON
KITTREDGE HILLS
VERMONT
NEW HAMPSHIRE


PRIMARY
IMPACT
AREA
HARDWICK
DAM
U.S.G.S. QUADRANGLES
HARDWICK, VT. 1951
PLAINFIELD, VT. 1953
Burlington Point
Caspian Lake
Cook Hill
Hardwick Center
East Hardwick
Mackville
H A R D W I C K
CALEDONIA CO
WASHINGTON CO
MOUNTAINS
W O O D B U R Y
D-1A

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ______ of ______

Subject: Inspection of non-federal dams

Computation: Hardwick Lake Dam — Job No. 953-05 Q

Computed by: MEB — Checked by: SDY — Date: 8-15-80

Hydrologic / Hydraulic Inspection

I) Performance at Test Flood Conditions

1) Maximum Probable Flood

a) Watershed classified as "Rolling"

b) Watershed Area

122.1 square miles – planimeter USGS sheet (avg. of three trials)

118 square miles – Vt. Public Service Commission

Caspian Lake, Eligo Pond, Long Pond, East Long Pond, Nichols Pond and Flagg Pond are contained within this drainage area. Their total surface area is less than 2% of the watershed area and their storage effect was not considered in the determination of peak inflow to Hardwick Lake.

c) From NED-ACE "Preliminary Guidance for Estimating Maximum Probable Discharges" Curve [illegible] for PMF [illegible]:

PMF ≅ 910 cfs / square mile

d) Peak Inflow

910 cfs / square mile × 122.1 square miles

≅ 111,000 cfs = PMF

Similarly, 1/2 PMF ≅ 55,500 cfs

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

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Subject: Inspection of non-federal dams

Computation: Hardwick Lake Dam

Job No. 953-050

Computed by: [illegible]

Checked by: SDM

Date: 8-15-80

2) Test Flood

a) Classification of Dams According to NED-ACE Recommended Guidelines

i) Size

Storage (max) ≅ 2100 acre-feet

Vt Dept. of Water Resources - 5 foot lake depth assumed at normal water level

Height ≅ 22.4 feet (This survey)

See Stage - Storage Curve p. 3

ii) Hazard Potential

A breach of the dam could cause failure of the Vermont Route 15 bridge just downstream of the dam. The sudden rise in stage of 6.3 feet would come within .3 feet of overtopping the bridge. Further downstream, a small rise in stage varying from 1.1 feet to 1.9 feet would flood a [illegible] amount of farmland in the relatively flat flood plain. [illegible] D/S [illegible] would [illegible] able the [illegible] would probably remain and suffer increased damage due to dam failure. The water depth at [illegible] would rise from 2 feet to 3 feet [illegible]

iii) Classification

Hazard: Significant

Size: Intermediate

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

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Subject: Inspection of non-federal dams

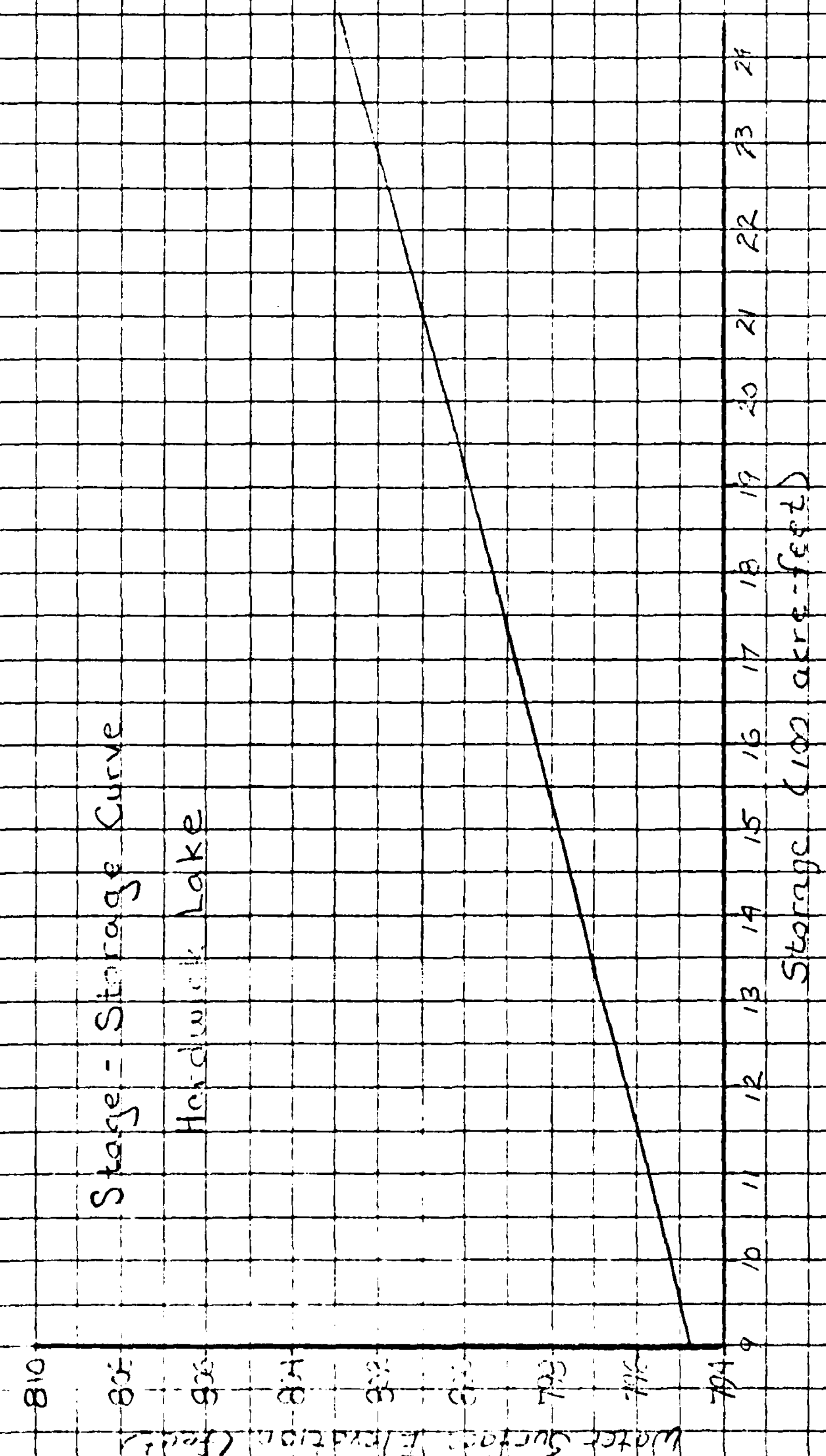
Computation: Hardwick Lake Dam

Job No. 953-05 Q

Computed by: MEB

Checked by: DM

Date: 8-15-80



@ Nat el 794.76 Surface Area = 180 acres 180 x 5' = 900 ac-ft - Vt Dept of Water Res

@ el 797.0 Surface Area = 194.9 acres (planimeter from USGS sheet)

Storage = 900 + 194.9 x 2.24' = 1337 acre ft

@ el 801.0 Storage = 1337 + 195 x 4' = 2117 acre ft say 2100 acre-ft max

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet_____ of _____

Subject: Inspection of non-fed dams Hardwick

Computation: Hardwick Dam

Job No. 953-0 [illegible]

Computed by: [illegible]

Checked by: [illegible]

Date: 8-8-80

3) Surcharge at Peak Inflow

a) Peak Inflow

Test Flood = 1/2 PMF = 55,500 cfs

b) Outflow Rating Curve

Outflow Rating Curve Computations
Hardwick Lake Dam

West Spillway El. 794.76 $Q = CLH^{3/2}$ C = 3.5 L = 82

H	Q	WS Elev	H	Q	WS Elev
1.24	396	796.0	11.24	[illegible]	806.0
2.24	962	797.0	13.24	13927	808.0
3.24	1674	798.0	15.24	[illegible]	810.0
5.24	3443	800.0	17.24	20544	812.0
7.24	[illegible]	802.0	19.24	24821	814.0
9.24	[illegible]	804.0	21.24	290?1	816.0

East Spillway El. 794.76 $Q = CLH^{3/2}$ C = 3.2 L = 62

H	Q	WS Elev	H	Q	WS Elev
1.24	274	796.0	11.24	7416	806.0
2.24	665	797.0	13.24	[illegible]	808.0
3.24	[illegible]	798.0	15.24	11E?9	810.0
5.24	[illegible]	800.0	17.24	14?02	812.0
7.24	[illegible]	802.0	19.24	16794	814.0
9.24	[illegible]	804.0	21.24	19?21	816.0

(assume form in gate structure) L = 13.05' D = 6' Invert Elev 792.0

Outlet Pipe $H = h_e + h_f + h_v$ $h_e = .1 V^2/2g$ $h_v = 1.0 V^2/2g$ $h_f = f \frac{L}{D} V^2/2g$ f = .014

h_f	V	Q	$1.11 V^2/2g$	H	WS Elev
.01	5.33	151	.49	0.5	792.5
.03	7.54	213	.97	1.0	793.0
.06	10.67	302	1.99	2.0	794.0
.08	12.33	354	[illegible]	> 2.76	> 794.76

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ____ of ____

Subject: Inspection of non-fed dams

Computation: Hardwick Dam

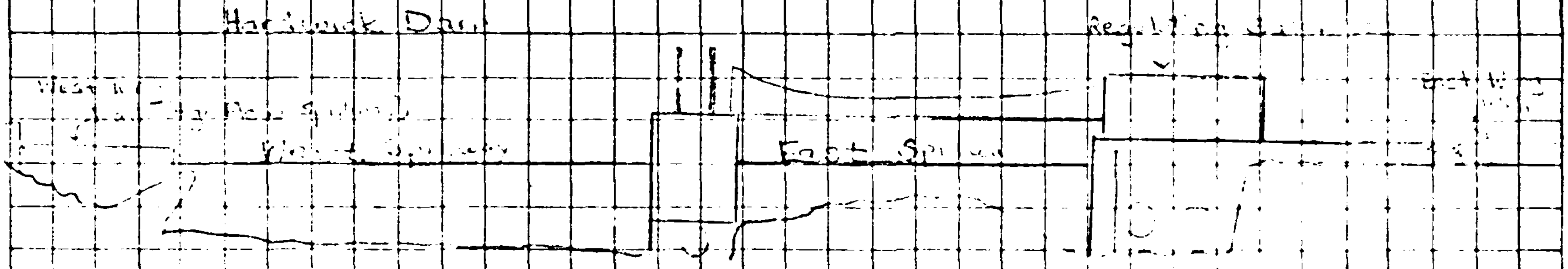
Job No. 953-05 Q

Computed by: MEB

Checked by: SDM

Date: 8-12-80

Hardwick Dam

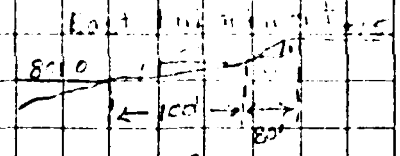


West Wing Wall Elev. 797.30 (?) L 38.7' $Q = CLH^{3/2}$ C = 3.0

H	Q	WS Elev	H	Q	WS Elev
.70	43	798.0	8.70	2974	806.0
1.70	[illegible]7	799.0	10.70	4064	[illegible]
2.70	575	800.0	12.70	52[illegible]	810.0
4.70	1185	802.0	14.72	[illegible]	812.0
[illegible]	[illegible]	804	[illegible]	71[illegible]	814.0

East Wing Wall L = 30 C = 3.0 $Q = CLH^{3/2}$ El 801.0

H	Q	WS Elev	H	Q	WS Elev
1.0	90	802.0	9.0	2430.0	810.0
3.0	[illegible]77	804.0	11.0	3283.0	812.0
5.0	1006.2	806.0	13.0	4215.6	814.0
7.0	[illegible]	[illegible]	15.0	[illegible]	816.0



Straight 15' wetted ...

Q	WS El
260	802.0
1411	804.0
3172	806.0
5389	808.0
8331	810.0
11711	812.0
15630	814.0

Center Sluiceway Flow $Q = CLH^{3/2}$ El 804.76 L = 15 C = 2.6

H	Q	WS El	H	Q	WS El	H	Q	WS El
1.24	[illegible]	806.0	5.24	468	810.0	9.24	1095	814.0
3.24	227	808.0	7.24	76[illegible]	812.0	11.24	14[illegible]	816.0

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ______ of ______

Subject: [illegible]

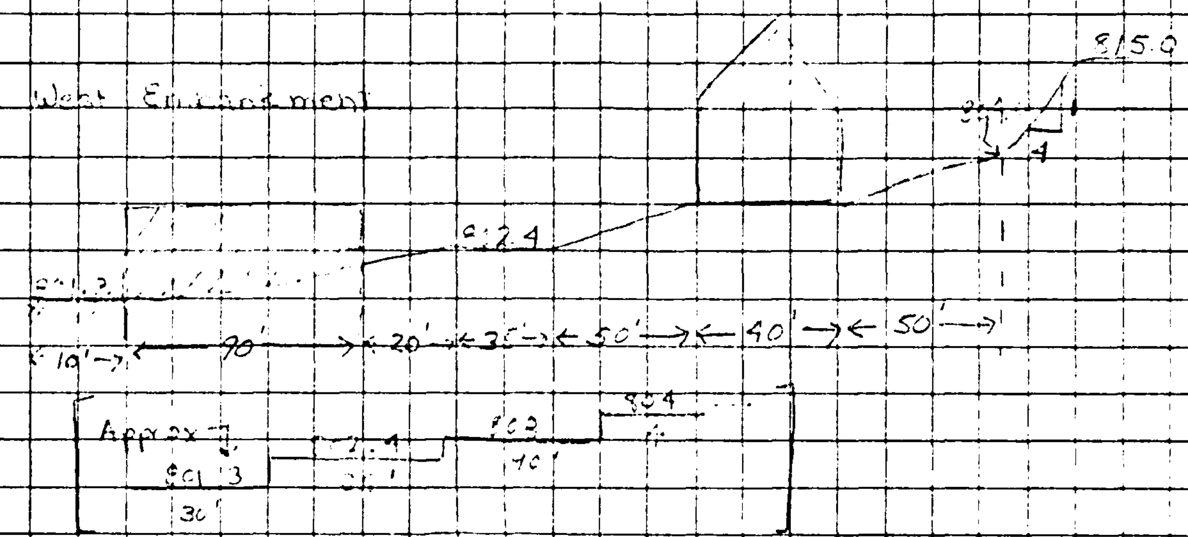
Computation: Hardwick Dam

Job No. [illegible]

Computed by: [illegible] Checked by: SDM Date: [illegible]

Hardwick Outflow Rating Curve cont.

West Embankment



Q	W.S. Elev.
93	802.4
236	803.0
1057	804.0

Q	W.S. Elev.
2740	806.0
7347	808.0
11051	810.0

Q	W.S. Elev.
17130	812.0

Rating Curve Total

W.S. El.	Q
796.0	1029
798.0	3253
800.0	6692
802.0	12243
804.0	23155

W.S. El.	Q
806.0	38612
808.0	57529
810.0	79429
812.0	[illegible]

The Outflow Rating Curve is plotted on the following page.

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ______ of ______

Subject: Inspection of non-Federal dams

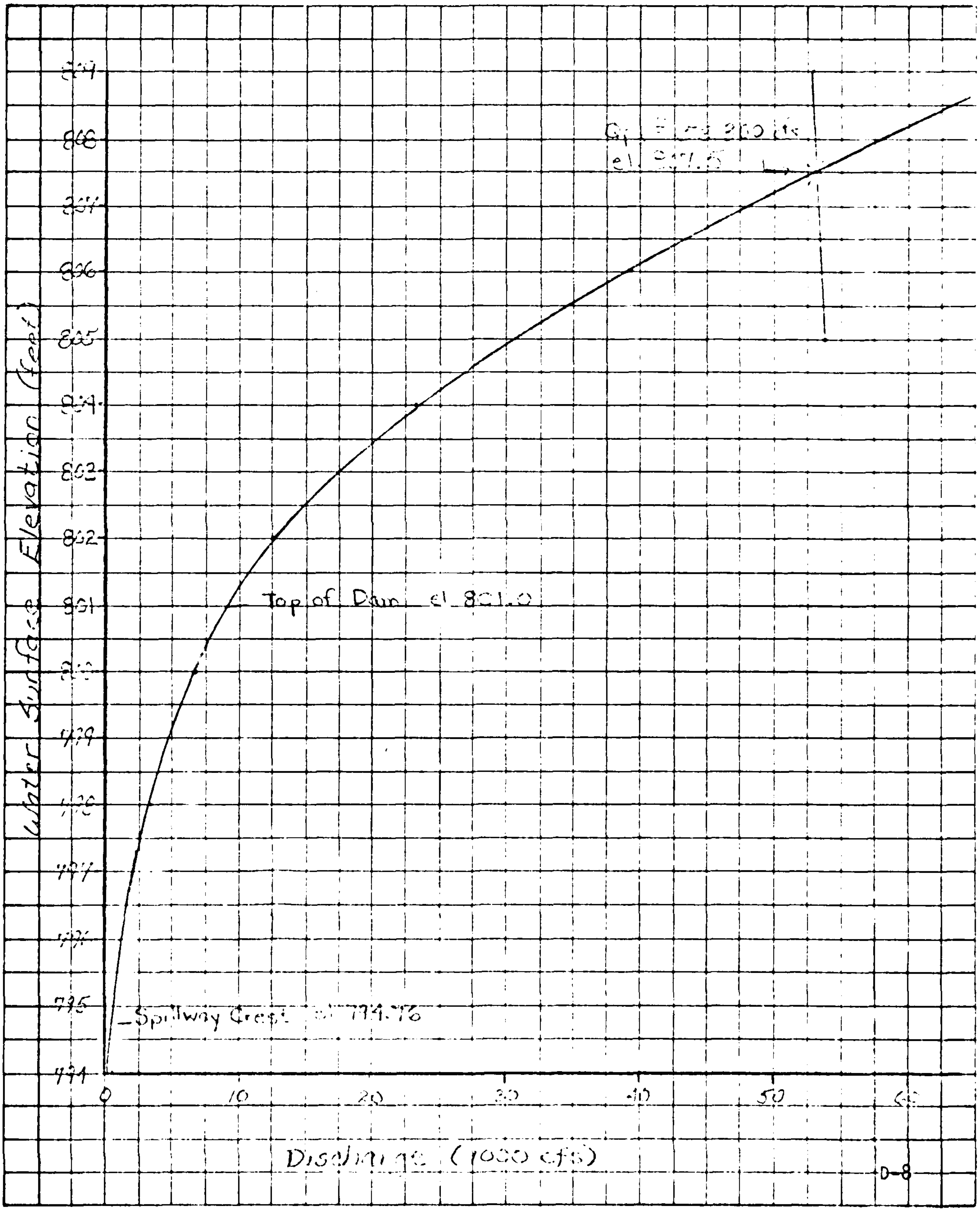
Computation: Hardwick Lake Dam

Job No. 958-[illegible]

Computed by: [illegible]

Checked by: SDM

Date: 8-15-80



D-8

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ____ of ____

Subject [illegible]

Computation [illegible] Job No. 952-05[illegible]

Computed by [illegible] Checked by SDM Date [illegible]

c) Surcharge Height to Pass Q_{P1}

1) [illegible] Test Flood = 1/2 PMF

Q_P = 55,500 cfs H = [illegible] - 794.[illegible] = 13'

d) Spillway Capacity to Top of Dam (el [illegible])

[illegible] spillway, east [illegible]

H = 6.24' Q_{SP} = 8400 cfs = 15% Q_{P1}

4) Effect of Surcharge on Maximum Probable Discharge

a) Lake Area @ flow line = 195 acres (see p. 3)

b) Assume normal pool level at spillway crest el. 794.76

c) Watershed area = 122.1 square miles

d) Discharge at various surcharge elevations

H = 14.24' V = 195 (14.24) = 2777 acre-feet

S = 2777/(122.1 × 53.3) = .43"

H = 10.24' V = 195 (10.24) = 1997

S = 1997/(122.1 × 53.3) = .31"

From Approximate Storage Routing Guidelines

(19" Max [illegible] New England)

Q_{P2} = Q_{P1} (1 - S/9.5) [illegible]

For H = 14.24 Q_{P2} = [illegible]041 cfs

H = 10.24 Q_{P2} = 53723 [illegible]

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ______ of ______

Subject: Inspection of [illegible] dam

Computation: [illegible] Lake Dam   Job No. 952-[illegible]

Computed by: [illegible]   Checked by: [illegible]   Date: [illegible]

e) Peak Outflow (Q_{P_2})

Using NED-ACE Guidelines [illegible] Storage Routing Alternate Method

$Q_{P_2} \cong 53,300$ cfs $H \cong 12.74$ for $Q_{P_1} = 1/2$ PMF

f) Spillway Capacity to Outflow

Spillway capacity to top of dam $= 8400$ cfs
∴ Spillway [illegible] 16% of the routed test flood outflow at 1/2 PMF

5) SUMMARY

a) Peak Inflow $Q_{P_1} \cong 55,500$ cfs
@ Test Flood = 1/2 PMF

b) Peak Outflow $Q_{P_2} \cong 53,300$ cfs
@ Test Flood = 1/2 PMF

c) Spillway Max Capacity

$Q_S \cong 8400$ cfs or (±) 16% of Q_{P_2}

Therefore, at Test Flood = 1/2 PMF, the dam is overtopped by 6.5 feet or to an average [illegible] of 12.74 feet above the spillway crest.

AD-A157 274 NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS HARDWICK LAKE DAM (VT..(U) EAST/WEST INDUSTRIES INC FARMINGDALE N Y OCT 80 2/2

UNCLASSIFIED F/G 13/13 NL

END

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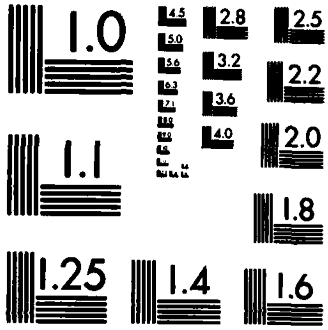

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ____ of ____

Subject: *Inspection of non-federal dams*

Computation: *Hardwick Lake Dam* Job No. *953-050*

Computed by: *MEB* Checked by: *CDM* Date: *8-19-80*

II Downstream Failure Hazard

1) Peak Failure Outflow

a) Breach Outflow

i) Mid-height (±) Elev 790.0 $(801 - 22/2 = 790)$

ii) Approx. Mid-Height Length ≅ 100 ft.
(Hardwick Village Dam Plans 1952)

iii) Breach width (see NED-ACE "Rule of Thumb Guidance for Estimating Downstream Dam Failure Hydrographs")
$W_b = 0.4 \times 100 \cong 40$ feet

iv) Assume surcharge to top of dam, therefore height at time of failure $h_0 = 22'$

v) Breach outflow $= Q_b = \frac{8}{27} W_b \sqrt{g}\, h_0^{3/2}$
$W_b = 40$
$h_0 = 22$
$Q_b = 6940$ cfs

b) Remaining Spillway Discharge

Assume [illegible] breach centered in primary spillway
Remaining Discharge:

1) Weir [illegible] L = 4? C = [illegible] $Q = CLH^{3/2}$

H	Q	W [illegible]
6.[illegible]	[illegible]91 cfs	[illegible]

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
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Subject: Inspection of non-federal dams

Computation: Hardwick Lake Dam — Job No. 953-05

Computed by: MSG — Checked by: [illegible] — Date: 8-19-80

(2) East Spillway $L = 62$ $C = 3.2$ $Q = CLH^{3/2}$

H	Q	WS Elev
6.24	3093 cfs	801.0

(3) Outlet Pipe WS el 801.0 $Q \cong 354$ (see page 4)

(4) West Wing Wall $L = 38.7'$ $C = 3.0$ $Q = CLH^{3/2}$

H	Q	WS Elev
3.70	826 cfs	801.0

∴ Remaining Spillway Discharge $= 2291 + 3093 + 354 + 826$
$= 6564$ cfs

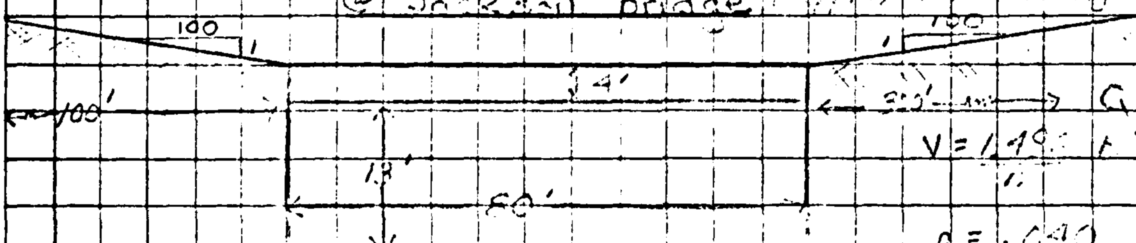
c) Peak Failure Outflow

Peak Failure Outflow = Breach Outflow + Remaining Spillway Discharge

$Q_p = 6940 + 6564 = 13504$ say 13500 cfs

2) Stage - Discharge Curves for Downstream River Reach

a) Immediately downstream from dam @ Jackson Bridge (within 100' reach)



$Q = AV$

$V = \frac{1.49}{n} r^{2/3} S^{1/2}$

$n = .040$

$s = .005$

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ____ of ____

Subject: Inspection of non-federal dams

Computation: Hardwood Lake Dam — Job No. 953-05 [illegible]

Computed by: MEB — Checked by: — Date: 8-19-80

Jackson Bridge cont.

H	A	P	R	V	Q
2	160	84	1.90	4.04	646
4	320	88	3.64	6.21	1988
6	480	92	5.22	7.90	3793
8	640	96	6.66	9.30	5955
10	800	100	8.00	10.51	8406
12	960	104	9.23	11.56	11097
13	1040	106	9.81	12.04	12521

Pressure Flow $Q = A\sqrt{\frac{2gH}{K}}$ $K = 1.5$ $H = 4'$ $Q = 13629$ cfs

Overland Flow $Q = CLH^{3/2}$ $C = 2.5$ L stepped in .5' increments

H (above bridge)			Q
.5			159
1.0			538

Stage - Discharge Curve plotted on p. 13

Flow prior to failure = Spillway capacity to top of dam
+ outlet pipe capacity
= 8400 cfs + 354 cfs
= 8754 cfs say 8750 cfs

Stage prior to failure = 10.4 feet

Flow following failure = 1350[illegible]
Stage following failure = 16.7 feet - .3 feet below roadway surface

Rise in stage = 16.7 - 10.4 = 6.3 feet

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ____ of ____

Subject: Inspection of non-fed dams

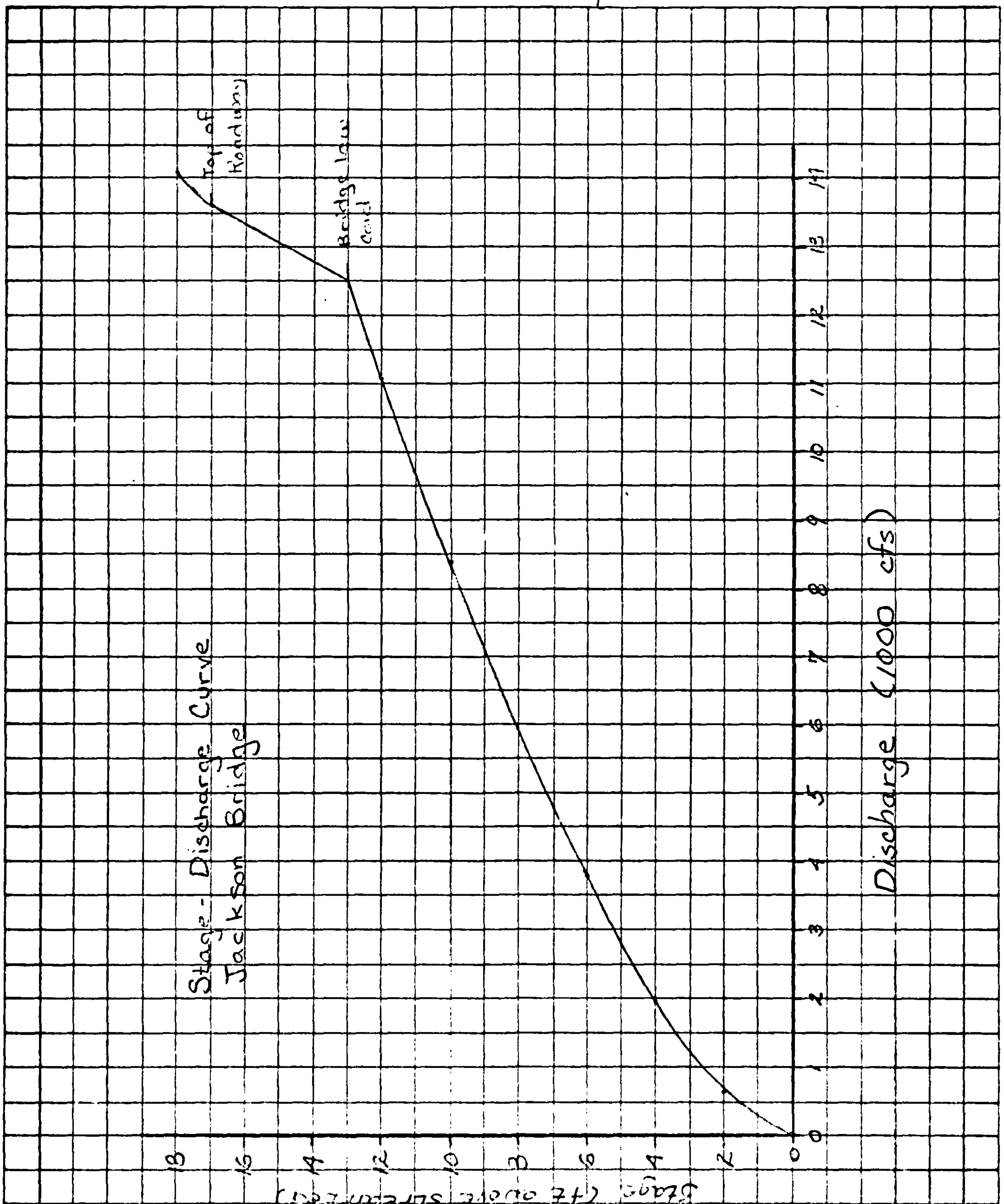
Computation: Hardwick Lake Dam

Job No. 953-05 Q

Computed by: MEB

Checked by: ____

Date: 8-20-80



JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ____ of ____

Subject: Inspection of non-federal dams

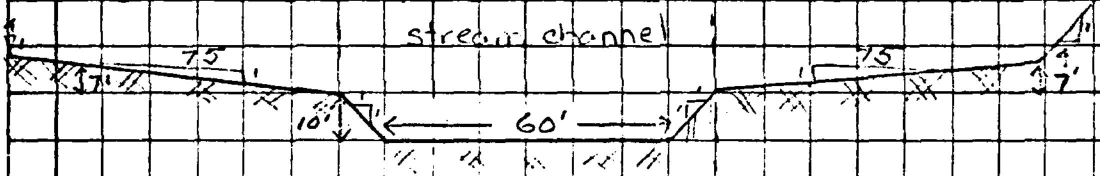
Computation: Hardwick Lake Dam

Job No. 953-050

Computed by: MEB   Checked by: SDM   Date: 8-20-80

Reach A

Typical Cross-section 100 - 3450 ft D/s of the Dam



$V = \frac{1.486}{n} R^{2/3} S^{1/2}$ $Q = AV$ $S = .002$

Stream Channel

H	A	P	R	V	Q
2	124	65.6	1.89	2.54	315
4	256	71.31	3.59	3.90	997
6	396	76.97	5.14	4.95	1961
8	544	82.63	6.58	5.84	3175
10	700	88.28	7.93	6.61	4624
12	860	88.28	9.74	7.58	6517
14	1020	88.28	11.55	8.49	8661
16	1180	88.28	13.37	9.36	11041
17	1260	[illegible]	14.27	9.78	12317

Flood Plain

H	A	P	R	V	Q	2Q (both banks)
12	150	150	1.00	0.66	100	199
14	600	300	2.00	1.05	633	1266
16	1350	450	3.00	1.38	1866	3732
17	1237.5	525	3.50	1.53	2815	5630

Stage - Discharge Curve plotted on the following page

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ______ of ______

Subject: Inspection of non-federal dams

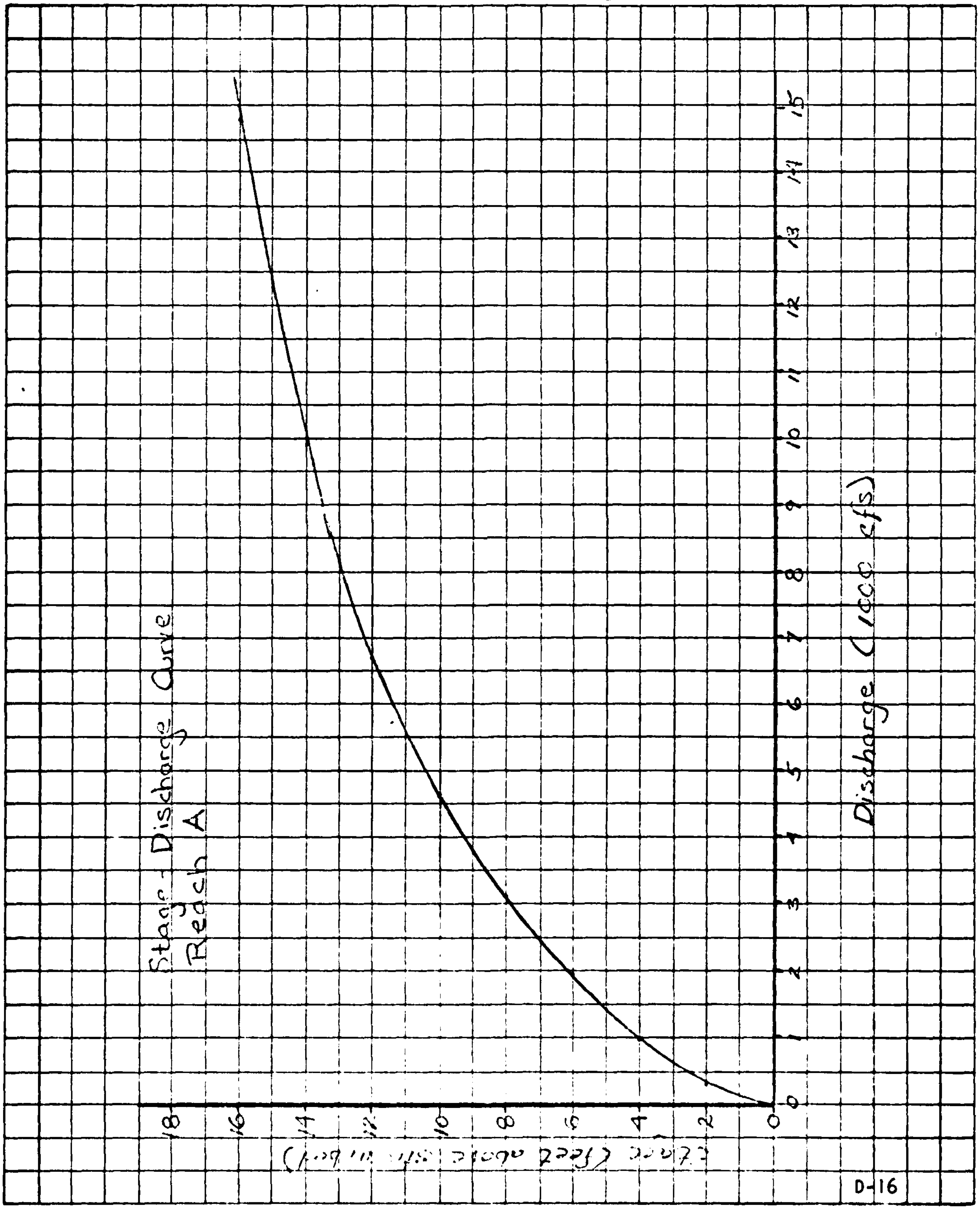
Computation: Hardwick Lake Dam

Job No. 753-05 G

Computed by: MEP

Checked by: SDM

Date: 8-20-80



JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ____ of ____

Subject: Inspection of non-federal dams

Computation: Hardwick Lake Dam

Job No. 953-05 T

Computed by: MEB

Checked by: DM

Date: 8-21-80

Reach A 100-3450 ft. D/s of Dam

Reservoir Storage at Time of Failure ≅ 2100 acre-ft

Stage Prior to Failure = 13.4 feet $Q = 8750$ cfs

Volume in Reach $= \frac{1839 (3350)}{43560} = 141$ acre-ft

Storage Routing

Volume in Reach (After Failure) $= \frac{3408.5 (3350)}{43560} = 262$ acre-ft

H = 15.5' curve p.15 $Q = 13500$ cfs

Volume in Reach Available for Storage = Failure Volume − Pre-failure Volume

$V_1 = 262 - 141 = 121$ acre-ft

121 -ft < ½ (2100) ∴ Reach O.K

$V_1 < \frac{1}{2} S$

Q_{P_2} (trial) $= Q_{P_1} \left(1 - \frac{V}{S}\right)$

$= 13500 \left(1 - \frac{121}{2100}\right)$

$\cong 12700$ cfs H = 14.2' V 181 − 141 = 40 a.f

$Q_{P_2} = Q_{P_1} \left(1 - \frac{V_{av}}{S}\right)$

$= 13500 \left(1 - \frac{(40 + 121)/2}{2100}\right)$

$\cong 13000$ cfs

Stage following failure ≅ 15.3'

$Q = 13000$ cfs

Raise in stage due to failure = 15.3 − 13.4 = 1.9'

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ____ of ____

Subject: Inspection of ... dams

Computation: Hardwick Dam

Job No. 953-05G

Computed by: [illegible]

Checked by: SDM

Date: 9-21-[illegible]

Reach B 3450 - 15000 ft D/S of Dam

Covered Railroad Bridge and R.R. embankment at D/S end of reach will determine stage at failure flow for a 11550 ft. stream reach assuming an average downstream slope of .002 from USGS sheet

Typical section for storage calculations same as Reach A.

Volume available for storage = $\frac{A_1 + A_2}{2}(L)$

L = length of reach

A_1 = Cross-sectional area Following Failure − Cross-sectional Area Prior to Failure at U/S end of river reach

A_2 = Cross-sectional Area Following Failure − Cross-sectional Area Prior to Failure at D/S end of reach (at Railroad Bridge)

$A_1 = 2230.75\ ft^2 - 1895.75\ ft^2 = 1332\ ft^2$ (see p. 16)

$A_2 = 11388.44\ ft^2 - 8476.44 = 2912\ ft^2$ (see p. 19)

H = 22.6'   H = 20.1'

$V_1 = \frac{(1332 + 2912)}{2}\frac{(11550)}{43560} = 563$ acre-feet

$V_1 < \frac{1}{2} S$

$563 < \frac{1}{2}(2100)$ ∴ Reach O.K.

Q_{p_2} (Trial) = $Q_{p_1}(1 - V_1/S)$

= 13050 (1 − 563/2100)

≐ 9500 cfs

$A_1 = 1332\ ft^2$

$A_2 = 3939 - 3476.44 = 462.56\ ft^2$

[illegible]

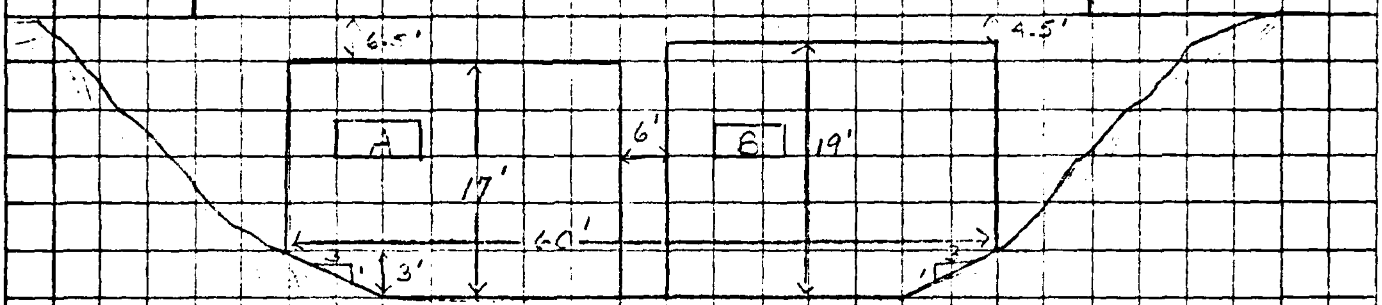
JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ______ of ______

Subject: Inspection of non-federal dams

Computation: Hardwick Lake Dam — Job No. 953-05 (1)

Computed by: MEB — Checked by: SDM — Date: 8-20-80



b) Covered Railroad Bridge -

Critical Section approx. 15000 feet D/s

$V = \frac{1.486}{n} R^{2/3} S^{1/2}$ $S = .002$ $n = .040$

Flow - Section A

H	A	P	R	V	Q
2	42	26.32	1.60	2.27	95
4	94.5	32.49	2.91	3.39	320
6	148.5	36.49	4.07	4.24	629
8	202.5	40.49	5.00	4.86	984
10	256.5	44.49	5.77	5.34	1370
12	310.5	48.49	6.40	5.73	1779
14	364.5	52.49	6.94	6.05	2204
16	418.5	56.49	7.41	6.31	2642
17	445.5	58.49	7.62	6.43	2865

Pressure Flow $Q = A\sqrt{\frac{2gh}{k}}$ $k = 1.5$

H	h	A	Q
19	2	445.5	4123
21	4	445.5	[illegible]
22.5	6.5	445.5	[illegible]

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ____ of ____

Subject: Inspection of non-federal dams

Computation: [illegible] Lake Dam

Job No. 95[illegible]

Computed by: [illegible]

Checked by: SDM

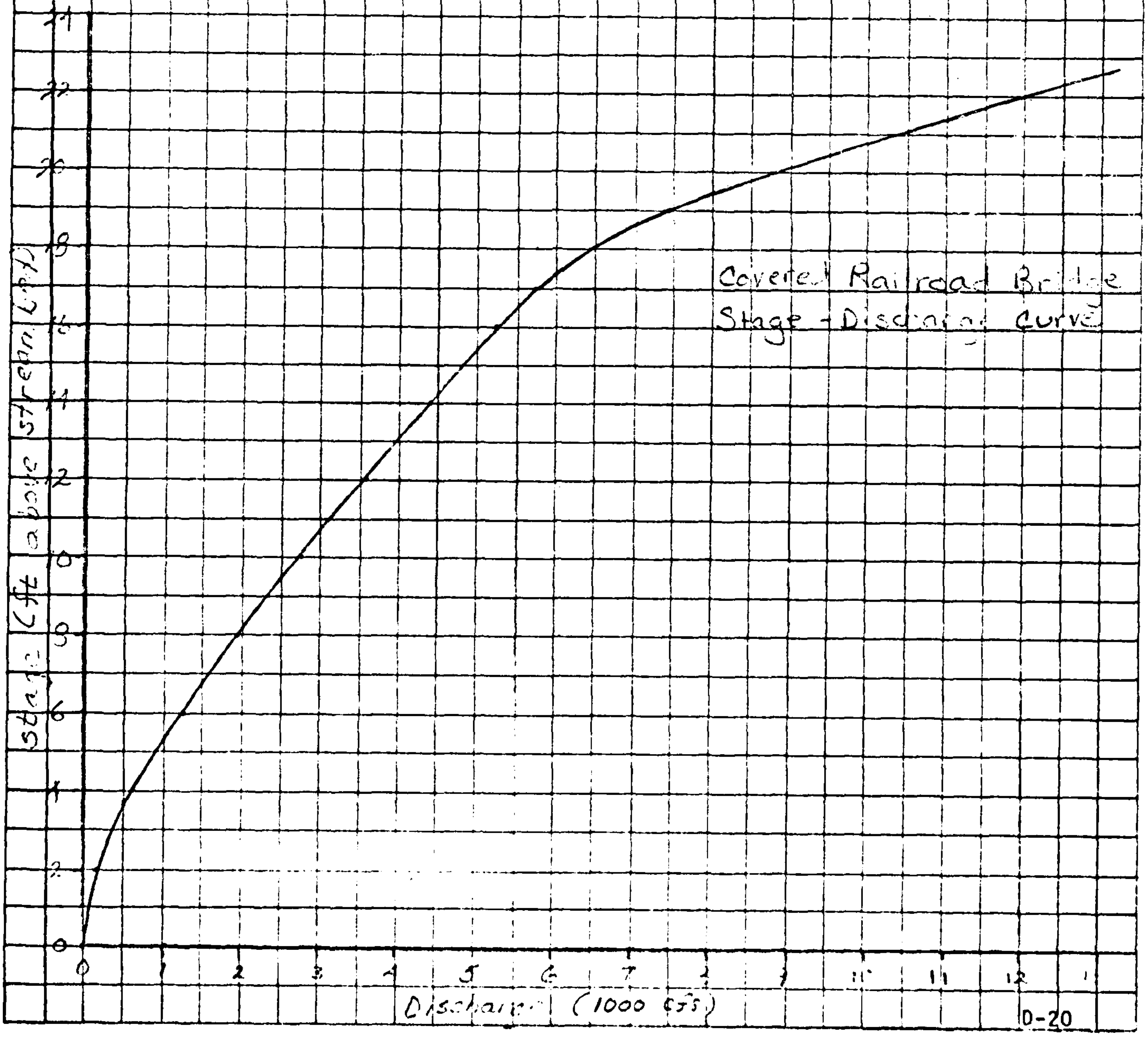
Date: 8-[illegible]

Flow - S[illegible] F (same as Section A [illegible] 17 feet)

H	A	P	R	V	Q
19	[illegible]	62.49	7.99	6.14	3[illegible]1

Pressure Flow Q = [illegible]

H	[illegible]	A	Q
21	2	499.5	4629
23.5	4.5	49[illegible]	6942



D-20

JAMES W. SEWALL COMPANY, OLD TOWN, MAINE
Civil and Sanitary Engineers

Sheet ____ of ____

Subject: Inspection of

Computation: Hydrology

Job No. 953-

Computed by:

Checked by: SDM

Date:

$V_2 = 1332 - \frac{(163.5)(11550)}{2 \quad 13500} = 238$ acre-ft

$Q_{P2} = Q_{P1}(1 - \frac{V_2}{S})$

$= 13010(1 - \frac{238}{510})$

$\cong 14500$ cfs $H = 21.1'$ at Bridge

Raise in Stage at Br. [illegible] $= 21.1' - 20' = 1.1$ feet

Summary

1) Peak Failure Outflow ≅ 13500 cfs

2) Raise in Stage in Immediate Impact Area

a) @ Jackson Bridge - Vt. Route 15 - Republic Hwy

Raise in Stage = 6.3', from 6.6 ft below roadway surface of bridge to 0.3 ft below the roadway surface

b) @ D/s end of Reach A ≅ 3450 ft D/s

Raise in Stage = 1.9', from maximum depth in the [illegible] of 3.6' to 5.3'. Increases flood area drastically.

c) @ D/s end of Reach B ≅ 15000 ft D/s

Covered Railroad Bridge

Raise in Stage = 1.1' from 3.4' below track elevation to 2.3' below track elevation. Increases flood area drastically. Increases depth of water at 1 or [illegible] commercial [illegible] [illegible] from 2 ft to 3 ft above floor

PRELIMINARY GUIDANCE

FOR ESTIMATING

MAXIMUM PROBABLE DISCHARGES

IN

PHASE I DAM SAFETY

INVESTIGATIONS

New England Division
Corps of Engineers

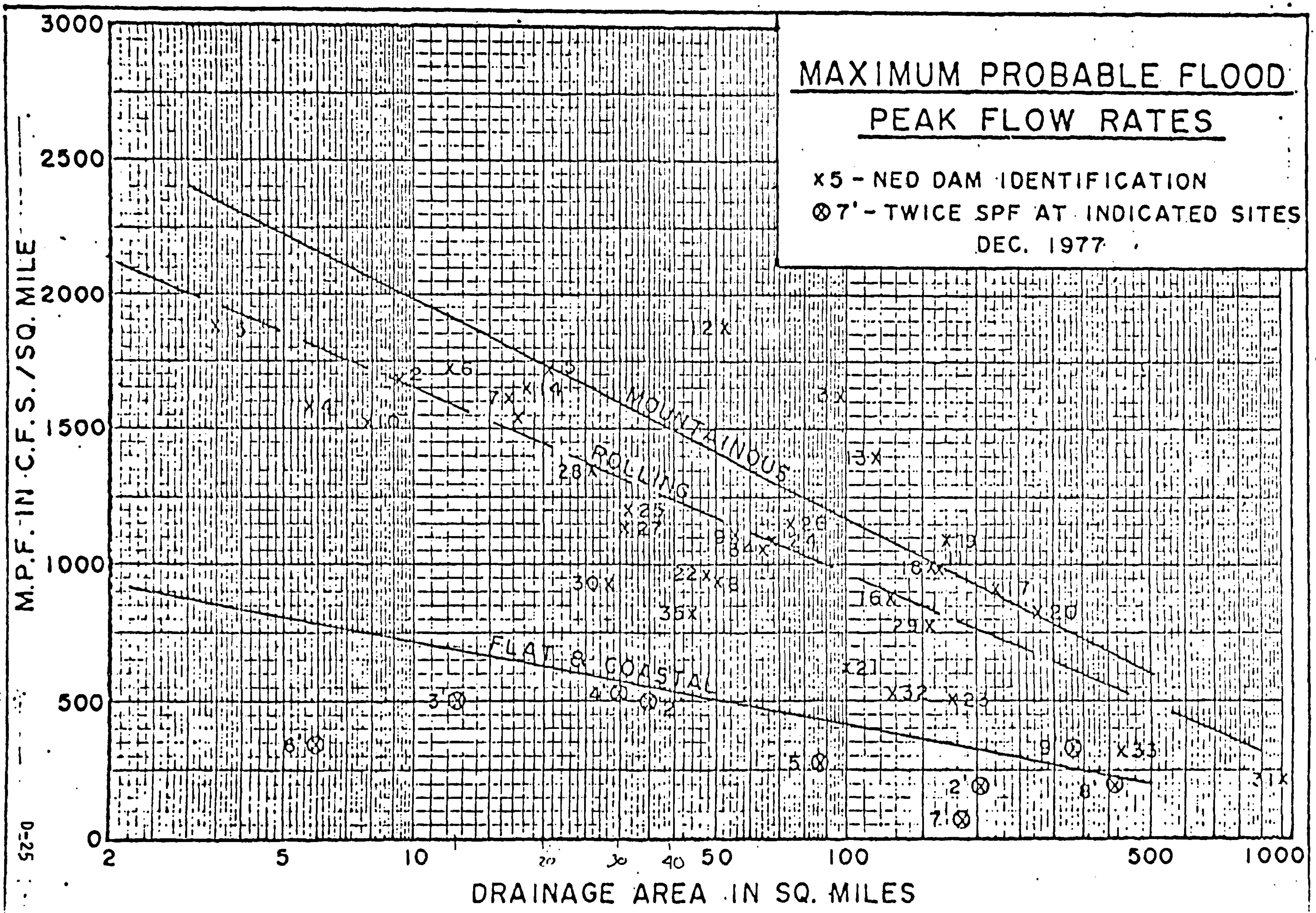
March 1978

MAXIMUM PROBABLE FLOOD INFLOWS
NED RESERVOIRS

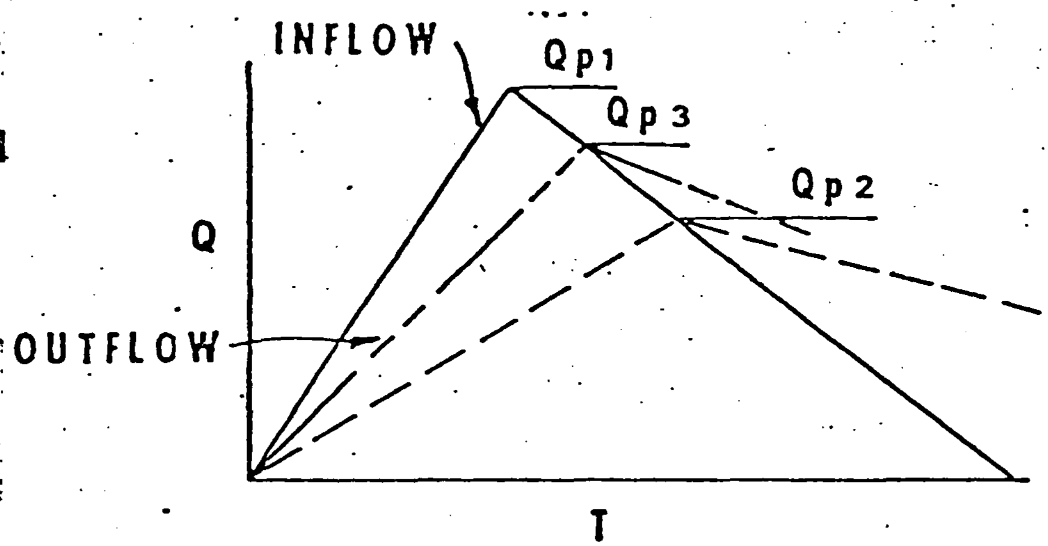
	Project	Q (cfs)	D.A. (sq. mi.)	MPF cfs/sq. mi.
1.	Hall Meadow Brook	26,600	17.2	1,546
2.	East Branch	15,500	9.25	1,675
3.	Thomaston	158,000	97.2	1,625
4.	Northfield Brook	9,000	5.7	1,580
5.	Black Rock	35,000	20.4	1,715
6.	Hancock Brook	20,700	12.0	1,725
7.	Hop Brook	26,400	16.4	1,610
8.	Tully	47,000	50.0	940
9.	Barre Falls	61,000	55.0	1,109
10.	Conant Brook	11,900	7.8	1,525
11.	Knightville	160,000	162.0	987
12.	Littleville	98,000	52.3	1,870
13.	Colebrook River	165,000	118.0	1,400
14.	Mad River	30,000	18.2	1,650
15.	Sucker Brook	6,500	3.43	1,895
16.	Union Village	110,000	126.0	873
17.	North Hartland	199,000	220.0	904
18.	North Springfield	157,000	158.0	994
19.	Ball Mountain	190,000	172.0	1,105
20.	Townshend	228,000	106.0(278 total)	820
21.	Surry Mountain	63,000	100.0	630
22.	Otter Brook	45,000	47.0	957
23.	Birch Hill	88,500	175.0	505
24.	East Brimfield	73,900	67.5	1,095
25.	Westville	38,400	99.5(32 net)	1,200
26.	West Thompson	85,000	173.5(74 net)	1,150
27.	Hodges Village	35,600	31.1	1,145
28.	Buffumville	36,500	26.5	1,377
29.	Mansfield Hollow	125,000	159.0	786
30.	West Hill	26,000	28.0	928
31.	Franklin Falls	210,000	1000.0	210
32.	Blackwater	66,500	128.0	520
33.	Hopkinton	135,000	426.0	316
34.	Everett	68,000	64.0	1,062
35.	MacDowell	36,300	44.0	825

MAXIMUM PROBABLE FLOWS
BASED ON TWICE THE
STANDARD PROJECT FLOOD
(Flat and Coastal Areas)

	River	SPF (cfs)	D.A. (sq. mi.)	MPF (cfs/sq. mi.)
1.	Pawtuxet River	19,000	200	190
2.	Mill River (R.I.)	8,500	34	500
3.	Peters River (R.I.)	3,200	13	490
4.	Kettle Brook	8,000	30	530
5.	Sudbury River.	11,700	86	270
6.	Indian Brook (Hopk.)	1,000	5.9	340
7.	Charles River.	6,000	184	65
8.	Blackstone River.	43,000	416	200
9.	Quinebaug River	55,000	331	330


MAXIMUM PROBABLE FLOOD
PEAK FLOW RATES
x5 - NED DAM IDENTIFICATION
⊗7' - TWICE SPF AT INDICATED SITES
DEC. 1977
MOUNTAINOUS
ROLLING
FLAT & COASTAL
M.P.F. IN C.F.S./SQ. MILE
DRAINAGE AREA IN SQ. MILES
3000
2500
2000
1500
1000
500
0
2
5
10
20
30
40
50
100
500
1000

ESTIMATING EFFECT OF SURCHARGE STORAGE ON MAXIMUM PROBABLE DISCHARGES



STEP 1: Determine Peak Inflow (Q_{p1}) from Guide Curves.

STEP 2: a. Determine Surcharge Height To Pass "Q_{p1}".

b. Determine Volume of Surcharge ($STOR_1$) In Inches of Runoff.

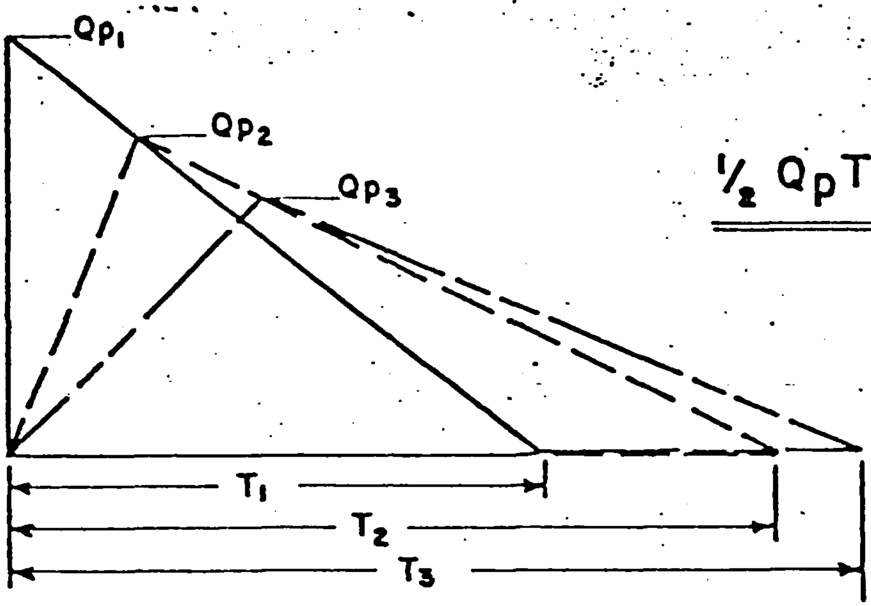
c. Maximum Probable Flood Runoff In New England equals Approx. 19", Therefore:

$$Q_{p2} = Q_{p1} \times \left(1 - \frac{STOR_1}{19}\right)$$

STEP 3: a. Determine Surcharge Height and "$STOR_2$" To Pass "Q_{p2}"

b. Average "$STOR_1$" and "$STOR_2$" and Determine Average Surcharge and Resulting Peak Outflow "Q_{p3}".

"RULE OF THUMB" GUIDANCE FOR ESTIMATING DOWNSTREAM DAM FAILURE HYDROGRAPHS



$$\frac{1}{2} Q_p T = 12\,S$$

STEP 1: DETERMINE OR ESTIMATE RESERVOIR STORAGE (S) IN AC-FT AT TIME OF FAILURE.

STEP 2: DETERMINE PEAK FAILURE OUTFLOW (Q_{p1}).

$$Qp_1 = \frac{8}{27} W_b \sqrt{g}\, Y_o^{3/2}$$

W_b = BREACH WIDTH - SUGGEST VALUE NOT GREATER THAN 40% OF DAM LENGTH ACROSS RIVER AT MID HEIGHT.

Y_o = TOTAL HEIGHT FROM RIVER BED TO POOL LEVEL AT FAILURE.

STEP 3: USING USGS TOPO OR OTHER DATA, DEVELOP REPRESENTATIVE STAGE-DISCHARGE RATING FOR SELECTED DOWNSTREAM RIVER REACH.

STEP 4: ESTIMATE REACH OUTFLOW (Q_{p2}) USING FOLLOWING ITERATION.

A. APPLY Q_{p1} TO STAGE RATING, DETERMINE STAGE AND ACCOPMANYING VOLUME (V_1) IN REACH IN AC-FT. (NOTE: IF V_1 EXCEEDS 1/2 OF S, SELECT SHORTER REACH.)

B. DETERMINE TRIAL Q_{p2}.

$$Qp_2(\text{TRIAL}) = Qp_1 \left(1 - \frac{V_1}{S}\right)$$

C. COMPUTE V_2 USING Q_{p2} (TRIAL).

D. AVERAGE V_1 AND V_2 AND COMPUTE Q_{p2}.

$$Qp_2 = Qp_1 \left(1 - \frac{V_{\text{[illegible]}}}{S}\right)$$

STEP 5: FOR SUCCEEDING REACHES REPEAT STEPS 3 AND 4.

APRIL 1978

APPENDIX E

INFORMATION AS CONTAINED IN

THE NATIONAL INVENTORY OF DAMS

NOT AVAILABLE AT THIS TIME

END

FILMED

9-85

DTIC